Volume 28 AUGUST, 1944 Number 8

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American Association *of* Petroleum Geologists

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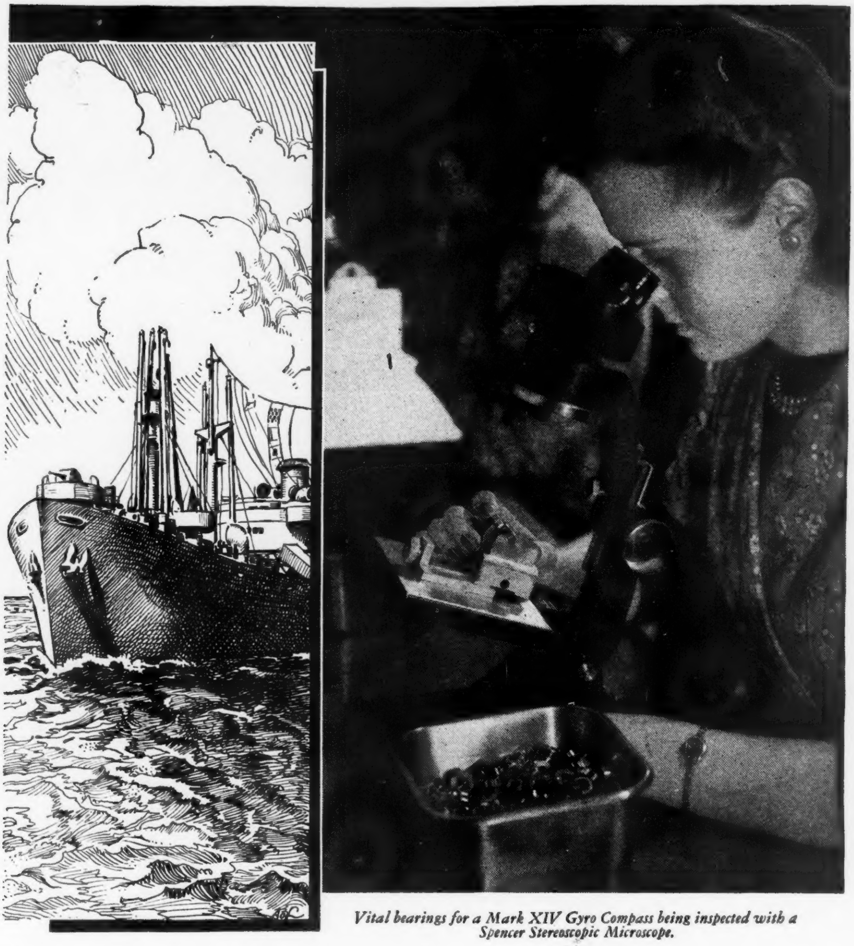

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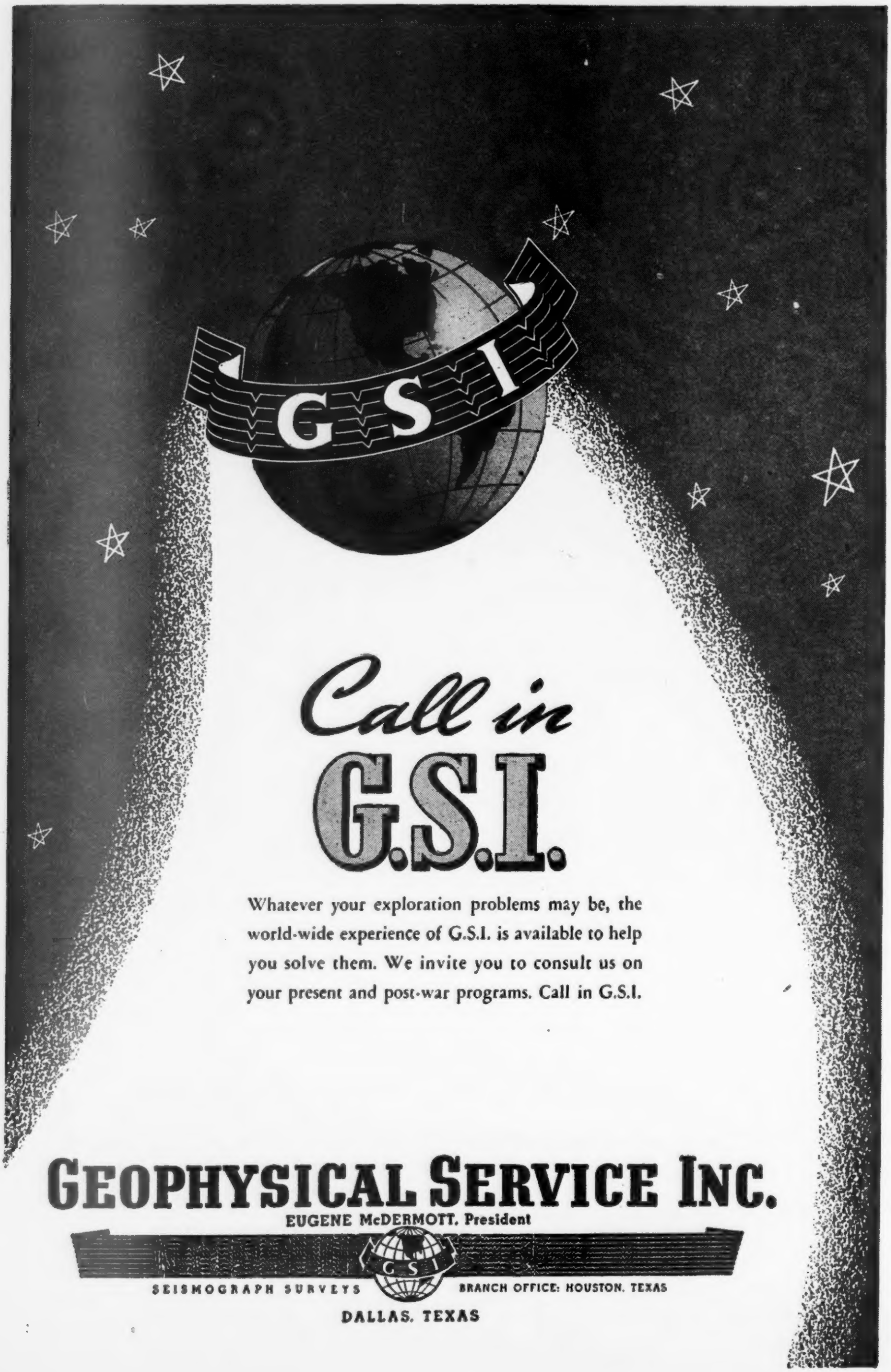
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Volume 28 Number 8

BULLETIN
of the
AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

AUGUST, 1944

CRETACEOUS FORMATIONS OF CENTRAL AMERICA AND MEXICO[1]

RALPH W. IMLAY[2]
Washington, D. C.

ABSTRACT

Cretaceous rocks in Central America and Mexico crop out over great areas, comprise many lithologic types, and range in thickness from a few thousand feet to more than 25,000 feet. Sources of sediments were mainly north, west, and south of the Mexican sea.

During the Neocomian, the sea was confined to the central part of the Mexican geosyncline, was indented by peninsulas in Coahuila and Oaxaca, and overlapped islands in eastern Mexico. Clastic deposits were formed near shore mainly during the Berriasian, lower Valanginian, and upper Hauterivian. Thin-bedded limestone and marl of Berriasian to Hauterivian ages characterize most of the Mexican geosyncline. The Barremian is represented offshore mainly by thick- to medium-bedded limestone, but nearshore contains some lenses of shale and sandstone and locally some gypsum.

During the lower Aptian the Mexican sea was apparently almost as restricted as during the Neocomian, but during the upper Aptian and Albian it spread widely and may have connected with the Pacific Ocean in both northern and southern Mexico. An angular unconformity may have been developed in southern Mexico during the lower and middle Albian. In northern Mexico a major change in sedimentation occurred in the lower Cenomanian and unconformities developed in marginal parts of the Mexican geosyncline. The lower Aptian consists mainly of thick- to medium-bedded limestone, but nearshore contains some shaly beds, arkosic sandstones, and in some places considerable gypsum. The upper Aptian and basal Albian are represented widely by shaly to thin-bedded limestone, but in southeastern Puebla and in Sonora include much coarse, clastic material.

The middle Albian and the upper part of the lower Albian are represented by a number of facies. Rudistid- or *Orbitolina*-bearing limestone, generally of considerable thickness, occurs over areas that were landmasses in Upper Jurassic or Neocomian time, or that were adjacent to landmasses. Throughout the central parts of the Mexican geosyncline occurs a thinner facies of thin-bedded limestone interbedded with much black chert that passes rather abruptly into the rudistid reefs. Along the present front of the Sierra Madre Oriental from Lampazos, Nuevo León, to Victoria, Tamaulipas, the rudistid reefs change eastward into a dense, thick-bedded limestone containing highly ornamented ammonites but no rudistids. Over the site of the Coahuila Peninsula gypsiferous beds are characteristic. In east-central Sonora are thousands of feet of interbedded limestone, shale, agglomerate, and lava. In the late middle Albian a thin unit of marl and thin-bedded limestone, comparable stratigraphically with the Kiamichi shale, was deposited over the northern parts of the Mexican states adjoining Texas.

The upper Albian and lower Cenomanian are represented throughout much of Mexico by wavy-bedded, thin-bedded limestone and many lenses of black chert that apparently were deposited in the offshore, deeper-water portion of the Mexican sea. This facies grades shoreward into marl and limestone similar to the Georgetown limestone or into a rudistid-miliolid-bearing limestone.

[1] Manuscript received, February 9, 1944. Published by permission of the director of the Geological Survey.

[2] Geologist, Geological Survey, United States Department of the Interior.

The Mexican sea during the upper Cenomanian and Turonian probably did not extend as far west as during the Albian, and its deposits are remarkably uniform over large areas. The greatest known downwarping occurred in southern Coahuila. In southern Mexico rudistid limestone predominates as far north as central Hidalgo and Querétaro. In north-central and eastern Mexico occurs a flag facies consisting of alternating beds of thinly laminated, platy limestone, shaly limestone, and shale that are poorly fossiliferous. In eastern Chihuahua and in Jeff Davis County, Texas, occurs a thick shale and marl facies that is highly fossiliferous. Over the site of the Coahuila Peninsula occurs a thin unit of highly fossiliferous shale and platy limestone. Sandstone interbedded with shale has been found in marginal areas of the Mexican geosyncline in Chihuahua, Zacatecas, and Guerrero.

The Mexican sea of the Coniacian and Santonian was considerably more restricted than during the Turonian and was being crowded eastward by rapidly rising landmasses in western Mexico as shown by thick sections of shale and sandstone in eastern Chihuahua. Thousands of feet of tuffaceous beds were deposited during the Coniacian in northern Zacatecas. Deposition of at least 5,000 feet of shale and some sandstone occurred in a trough extending eastward across southern Coahuila into west-central Nuevo León. In northeastern Mexico this shale passes northward into the much thinner Austin chalk and southward into the much thinner San Felipe limestone. A thick, rudistid-bearing limestone is fairly common in Central America and southern Mexico as far north as southeastern San Luis Potosí. The landmass south of the Mexican sea does not appear to have furnished much coarse sediment.

The sea during the Campanian and Maestrichtian became more and more restricted as shown by the occurrence of coarse conglomerate and coal beds in eastern Chihuahua and northern Coahuila, of fine conglomerate in southwestern Coahuila, of large quantities of sandstone as far east as western Nuevo León and eastern San Luis Potosí, and by the occurrence of more coarse materials in the Maestrichtian than in the Campanian beds. About 20,000 feet of coarse, clastic sediment was deposited in a trough extending eastward across southern Coahuila. Thousands of feet of continental beds were deposited in the Cabullona area of northeastern Sonora. A much thinner shale facies was deposited in Tamaulipas, northern Veracruz, and eastern Nuevo León. Thousands of feet of shale and sandstone occur in southern Nicaragua. Rudistid-bearing limestone associated with shale and sandstone extends from southeastern San Luis Potosí southward into Central America. At the end of the Maestrichtian the sea withdrew completely from the interior of Mexico.

INTRODUCTION

This report is a synthesis and interpretation of existing knowledge concerning the Cretaceous formations of Central America and Mexico. Its purpose is to assemble in convenient form such stratigraphic data as will facilitate petroleum exploration. It emphasizes spatial rather than time relationships. It indicates those areas where detailed studies would add much to our knowledge of the distribution of land and sea in Cretaceous time. The paleogeographic maps should be regarded merely as preliminary interpretations, subject to considerable alterations by future workers. Baja California and western Sonora have not been discussed, as they belong to the Pacific Coast province and should be considered in connection with the Cretaceous deposits of California. The word rudistid as used herein refers to the aberrant pelecypods included in the Pachyodonta and Rudistae.

ACKNOWLEDGMENTS

The writer has drawn heavily on the masterly treatment by Carlos Burckhardt entitled, "Étude synthétique sur le mésozoïque méxicain," which summarizes knowledge concerning the Mexican Mesozoic until the late 1920's. Also, considerable information has been gleaned from the excellent but involved papers of Emile Böse. The papers of many other geologists associated with or preceding Burckhardt and Böse have been consulted and are discussed herein. Among the more important contributors are J. G. Aguilar, C. L. Baker, G. Boehm, J. A. Cushman, E. T. Dumble, Johannes Felix, R. T. Hill, R. A. Jones, J. L. Tatum,

E. A. Trager, W. A. Ver Wiebe, Paul Waitz, and B. C. Belt. More recently, important contributions for Central America have been made by Karl Sapper, F. K. G. Mullerried, and Charles E. Weaver; for southern Mexico by F. K. G. Mullerried; for eastern Mexico by John M. Muir, Arnold Heim, R. W. Barker, and A. R. V. Arellano; and for northern Mexico by L. B. Kellum, W. A. Kelly. R. E. King, T. S. Jones, W. S. Adkins, Wm. E. Humphrey, Wm. G. Kane, N. L. Taliaferro, Gonzalo Vivar, and Jorge Cumming.

STRATIGRAPHIC SUMMARY

NEOCOMIAN

At the beginning of the Cretaceous the Mexican sea transgressed the bordering lands in many places (Figs. 1 and 2). Toward the north it lapped against the southern margin of the Diablo Plateau area of western Texas, around the Coahuila Peninsula of western Coahuila, probably around a smaller peninsula in the vicinity of the Burro Mountains of northern Coahuila, and thence eastward along the southern margin of the Central Mineral region of Texas. Toward the east it overlapped an island in the area between Huizachal and Galeana in southwestern Tamaulipas, and another island in the Huasteca area. Toward the south it lapped against a mass of gneissic and granitic rocks in the southern parts of the states of Guerrero, Oaxaca, and Chiapas, and around a northward-projecting peninsula in east-central Oaxaca. It probably extended westward through Colima and Jalisco and southeastward into northern Central America, but faunal evidence of such an extension is lacking. Its western margin in the area of Chihuahua, Durango, and Zacatecas is not known, as the western parts of those states are still unexplored geologically.

Thick, coarse, clastic sediments of lower and middle Neocomian age, indicating the proximity of the shore line, have been included in the Las Vigas formation of the Malone and southern Quitman mountains of western Texas, in the Las Vigas formation of the lower part of the Conchos Valley of eastern Chihuahua, in the Carbonera and Las Vigas formations of the mountains just west of the Laguna district in eastern Durango, and in the San Marcos arkose of east-central Coahuila. Similar unnamed, coarse deposits occur in southern Nuevo León near Galeana, Tamaulipas, and in the Pungarabato-Huetamo area of northern Guerrero and southeastern Michoacán. Sandy beds are present near the base of the Neocomian section in the western part of the Sierras de Parras and Jimulco in southern Coahuila, in the Miquihuana-Huizachal area of southwestern Tamaulipas, and in the Cintalape area of southern Chiapas. Coal-bearing shale near Huayacocotla in northern Veracruz must reflect the presence of a near-by landmass. The coarse, clastic sediments vary considerably in character and thickness from place to place, probably depending on the positions of the rivers or of local uplifts, and are mainly of Berriasian, lower Valanginian, and upper Hauterivian ages. Limestone deposition near shore occurred during the upper Valanginian, lower Hauterivian, and Barremian stages. This general se-

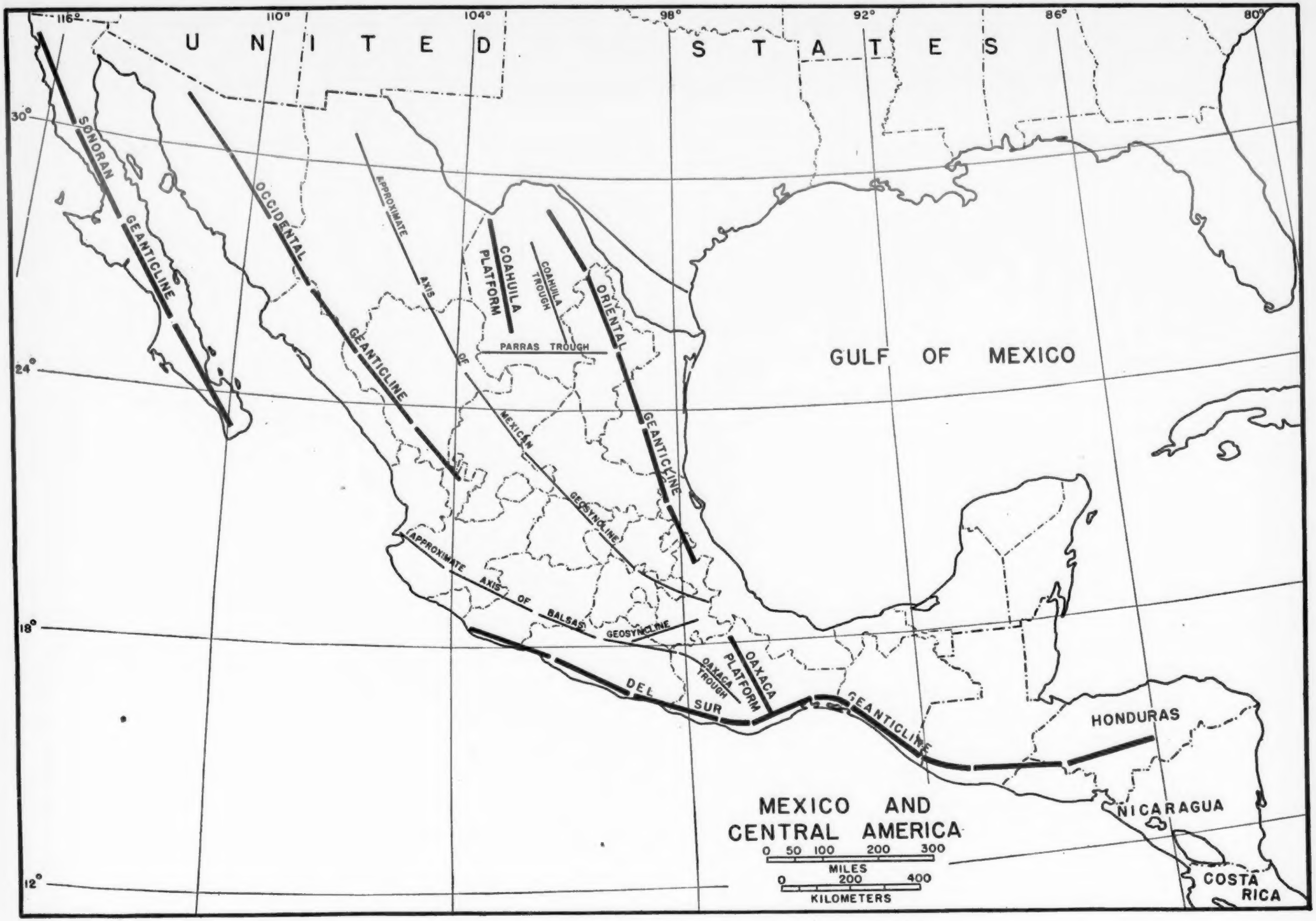


FIG. 1.—Some geanticlines and geosynclines of central America and Mexico.

FIG. 1.—Some geanticlines and geosynclines of central America and Mexico.

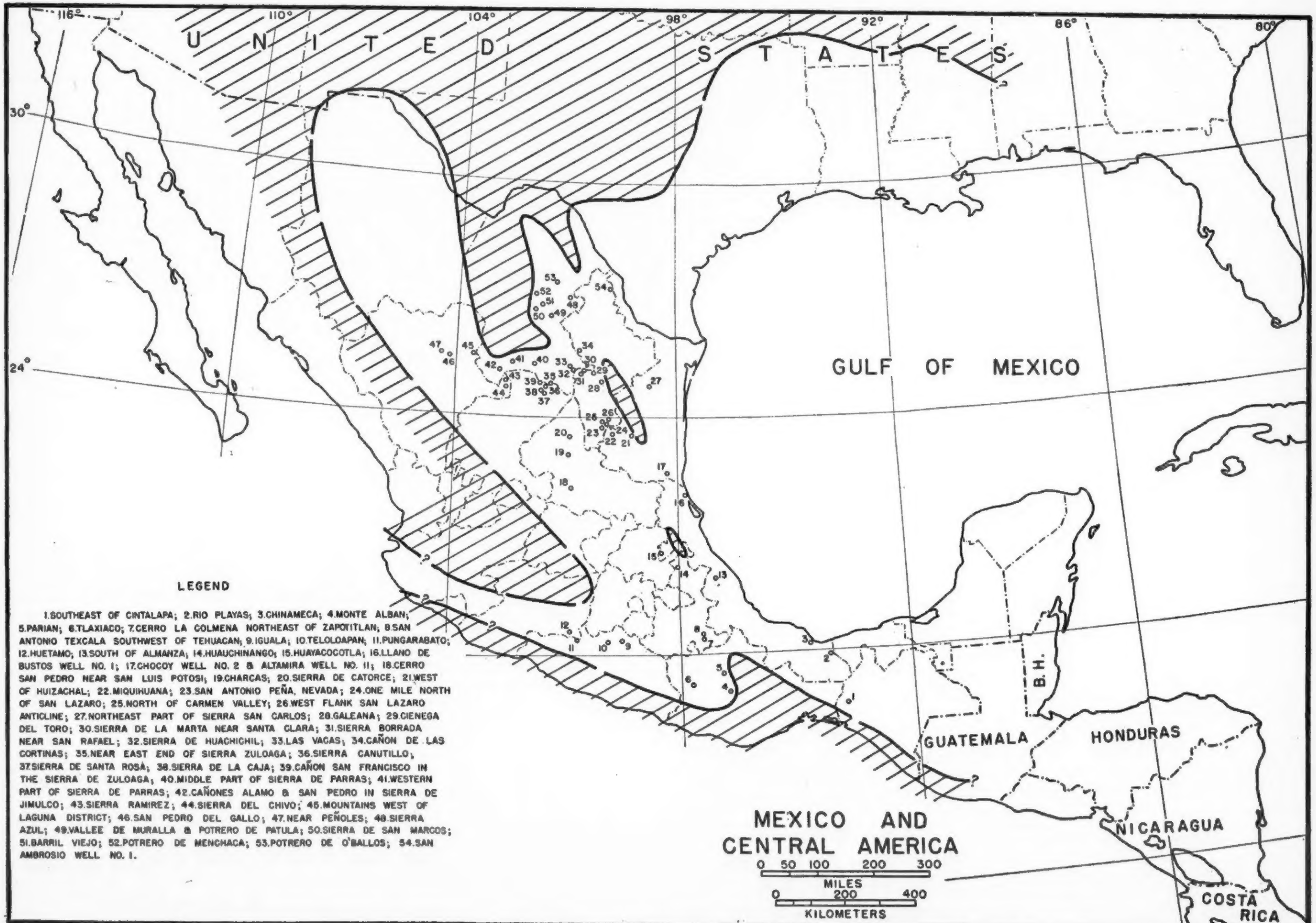


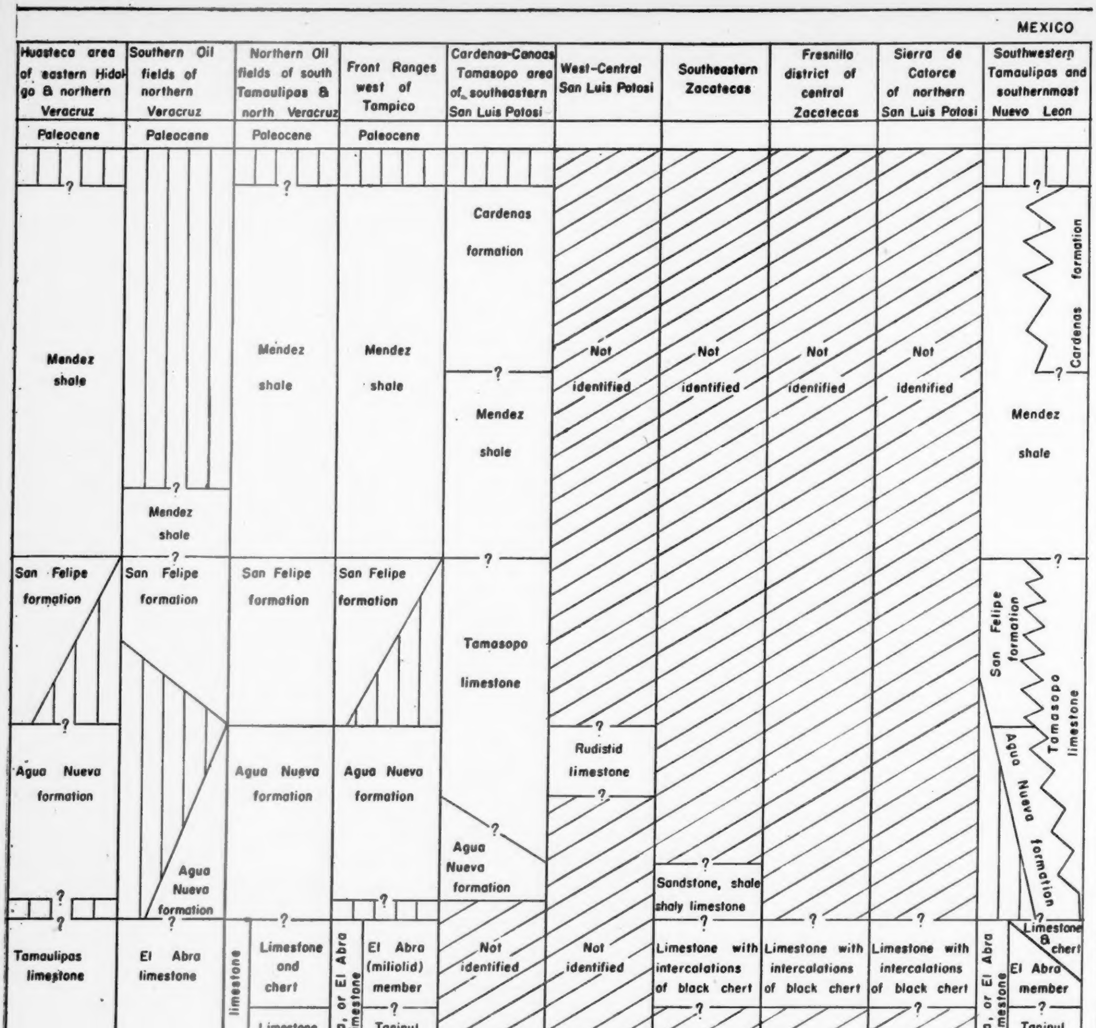
FIG. 2.—Neocomian fossil localities in Central America and Mexico.

TABLE I—CORRELATION OF CRETACEOUS FORMATIONS OF CENTRAL AMERICA AND MEXICO

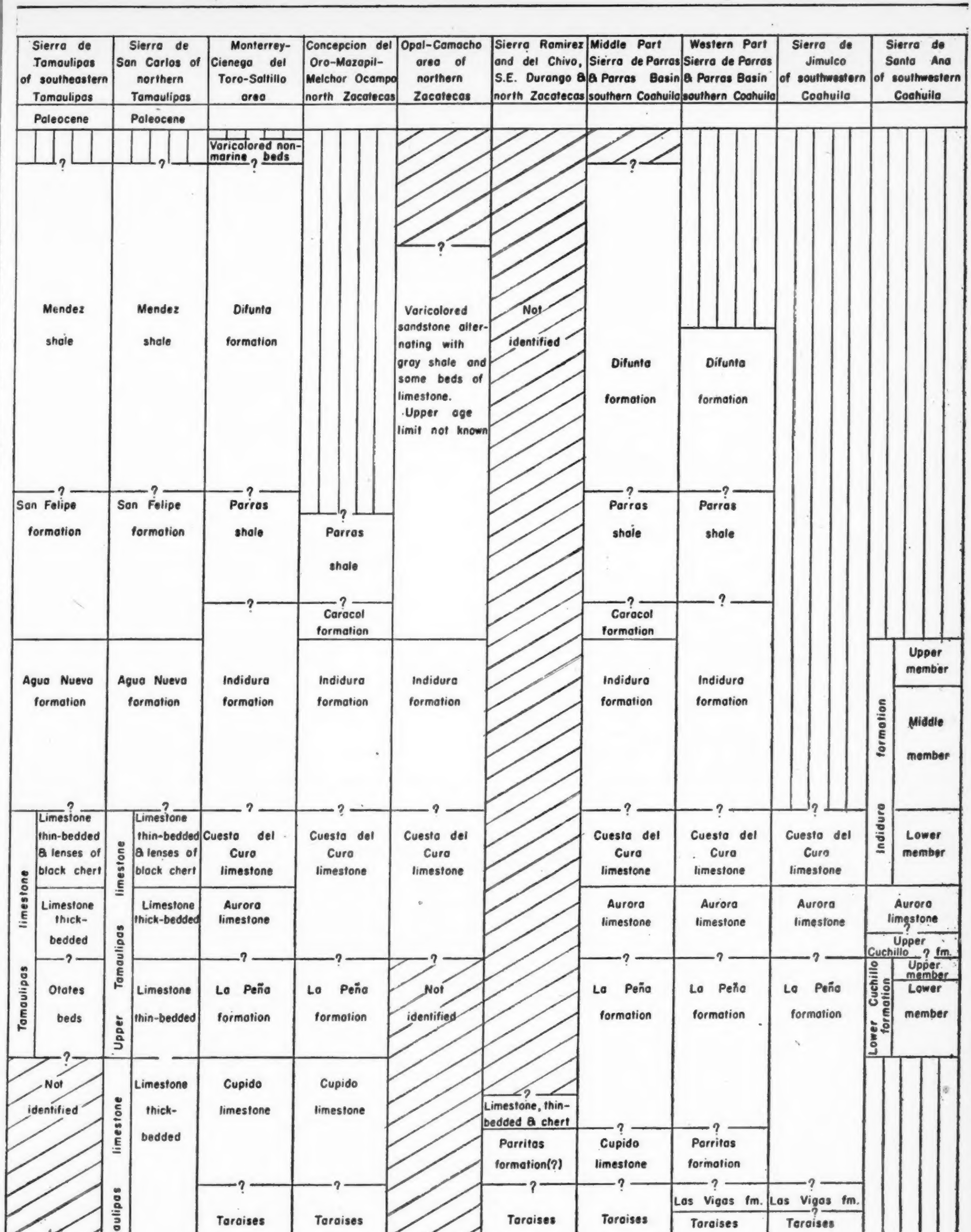
GENERALIZED STANDARD SECTIONS				CHARACTERISTIC FOSSILS		CENTRAL AMERICA		
SERIES		EUROPEAN STAGES	TEXAS AND MEXICO	AMMONITES	OTHER FOSSILS	Southern Nicaragua	El Salvador, Honduras, and southern Guatemala	British Honduras and northern Guatemala
			OVERLYING ROCKS					
UPPER CRETACEOUS	?	DAÑIAN	HIATUS			Not identified	Not identified	Not identified
UPPER CRETACEOUS	GULF	MAESTRICH-TIAN	NAVARRO	Sphenodiscus; Placenticeras cf. P. meeki	Tampsia and Titanosarcolites; Coralliochama g.boehmi; Exogyra costata; Exogyra cancellata	? Shale and sandstone with much volcanic material.	? Esquias formation	? San Cristobal formation
UPPER CRETACEOUS	GULF	CAMPANIAN	TAYLOR	Placenticeras cf. P. meeki; Texanites	Exogyra ponderosa			
UPPER CRETACEOUS	GULF	SANTONIAN	AUSTIN	Texanites texanus and Canadoceras flaccidicostum; Texanites	Sauvagesia cf. S. degolyeri; Inoceramus undulatoplicatus; Exogyra	? Not identified		
UPPER CRETACEOUS	GULF	CONIACIAN	AUSTIN	Gauthiericeras cf. G. margae; Barroisiceras cf. B. haberfellneri and Peroniceras aff. P. subtricarinatum				
UPPER CRETACEOUS	GULF	TURONIAN	EAGLE FORD	Prionotropis aff. P. hyatti and abundant Coilopoceras; Prionotropis cf. P. woolgari and abundant Romaniceras; Vascoceras, Fagesia, Neoptychites, and Metoicoceras cf. M. whitei	Ostrea lugubris; Hippurites mexicanus; Inoceramus cf. I. fragilis; Exogyra cf. E. olisiponensis; Inoceramus labiatus; Gryphaea kellumi; Exogyra arietina var coahuilensis			? Coban limestone (also called Ixcoy and Comitan limestone)
UPPER CRETACEOUS	GULF	CENOMANIAN	EAGLE FORD / WOODBINE ?	Mantelliceras aff. M couloni and Acanthoceras spp.; Sharpeiceras sp.	Coalcomana ramosa			
LOWER CRETACEOUS	COMANCHE	CENOMANIAN / ALBIAN	WASHITA	Budaiceras & Mantelliceras cf M. mantelli, Adkinsia, Turrilites brazoensis; Stoliczkaia; Prohysteroceras; Pervinquieria; Hysteroceras	Pecten roemeri, Exogyra cartledgei; Exogyra arietina		? Limestone, marl, conglomeratic limestone	
LOWER CRETACEOUS	COMANCHE	ALBIAN	FREDERICKS-BURG	Pervinquieria maxima, Desmoceras brazoense, Oxytropidoceras belknapi, Dipoloceras cristatum, Oxytropidoceras acuticarinatum, Knemiceras	Inoceramus subsulcatiformis, Toucasia texana, T. patagiata; Exogyra texana; Gryphaea mucronata			
LOWER CRETACEOUS	COMANCHE	ALBIAN / APTIAN	TRINITY	Douvilleiceras mammilatum; Sonneratia; Douvilleiceras cf. D. nodosocostatum; Dufrenoya texana and Pedioceras, Ammonitoceras, Procheloniceras; Acanthoplites; Columbiceras; Hypacanthoplites; Lyelliceras	Orbitolina texana; Exogyra quitmanensis			
LOWER CRETACEOUS	COAHUILA	APTIAN	NUEVO LEON	Parancyloceras; Pseudohaploceras; Costidiscus cf. C. recticostatus			? Upper part of Metapan (Probably same as Tegucigalpa formation)	? Upper part of Todos Santos beds
LOWER CRETACEOUS	COAHUILA	NEOCOMIAN: BARREMIAN	NUEVO LEON	Pulchellia; Holcodiscus; Barremites				
LOWER CRETACEOUS	COAHUILA	NEOCOMIAN: HAUTER-IVIAN	DURANGO	Olcostephanus sp; Olcostephanus raricostatus and Leopoldia, Acanthodiscus cf. A. radiatus; Olcostephanus	Exogyra reedi			
LOWER CRETACEOUS	COAHUILA	NEOCOMIAN: VALANGIN-IAN	DURANGO	Rogersites, Valanginites, and Dichotomites; Thurmannites miquihuanensis and T novihispanicus				
LOWER CRETACEOUS	COAHUILA	NEOCOMIAN: BERRIAS-IAN	DURANGO	Berriasella, Subthurmannia, Spiticeras, Himalayites, Protacanthodiscus, and Neocosmoceras.				
			UNDERLYING ROCKS				JURASSIC	JURASSIC

MEXICO

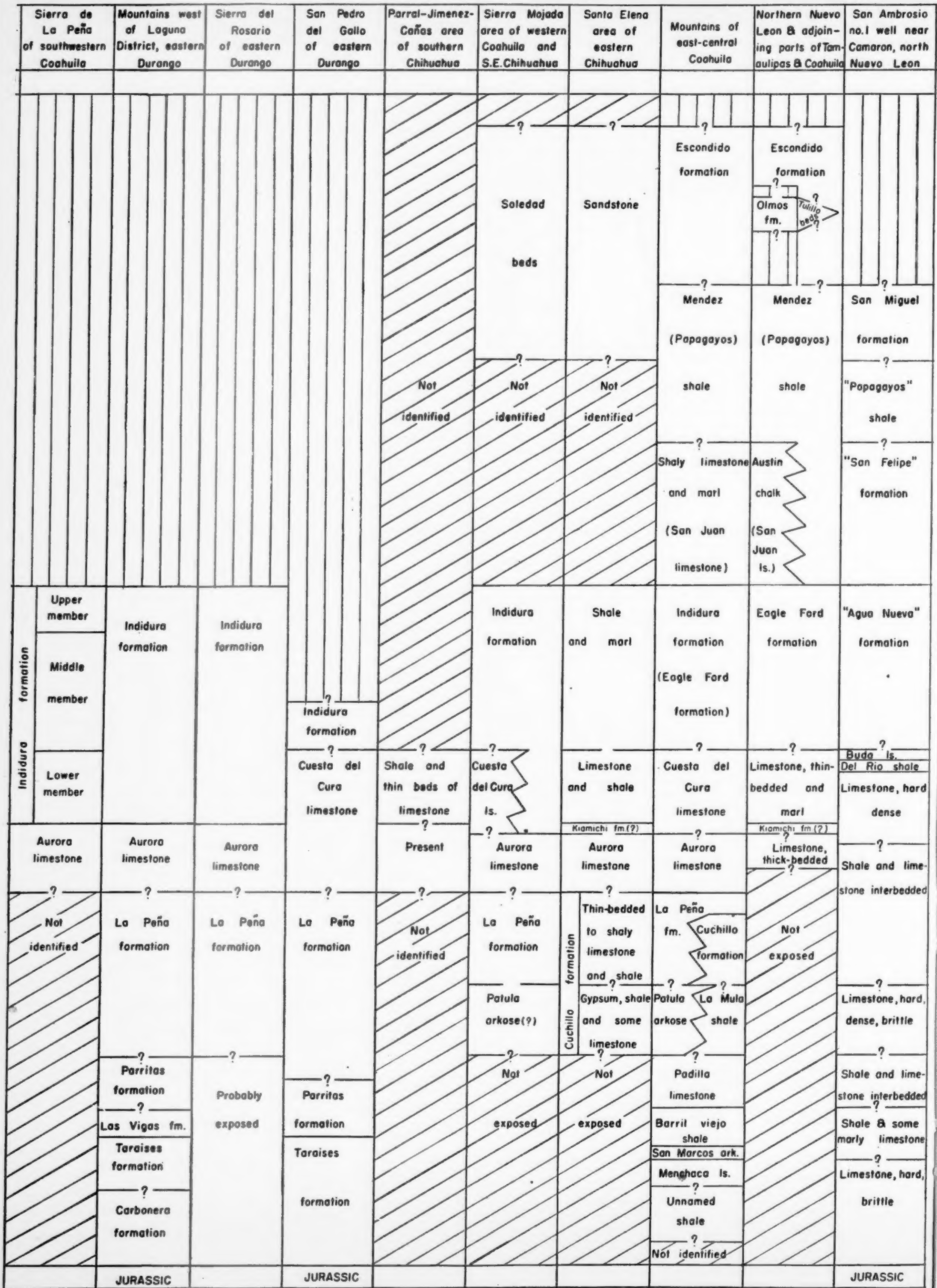
Chiapas and Tabasco	Isthmus of Tehuantepec Eastern Veracruz & eastern Oaxaca	West-Central Oaxaca	Colima, southern Jalisco, and western Michoacan	Pungarabato-Huetamo area, North Guerrero & S.E. Michoacan	Zumpango del Rio in east-central Guerrero	Morelos and adjoining parts Puebla, Guerrero, & Mexico State	Eastern Queretaro, western Hidalgo and northern Mexico.	Tehuacan-Zapotitlan-San Juan Raya area of S.E. Puebla.	Orizaba-Jalapa-Cordoba area of central Veracruz
Eocene									
Not identified ? San Cristobal formation	Not identified	Not identified	Not identified	Not identified	Not identified ? Marl, sandstone and limestone	Not identified	Not identified	Not identified	Not identified
? Coban limestone (also called Sierra Madre and White limestone)	? Coban limestone	? Rudistid Limestone	? Thick-bedded, rudistid limestone Marl at base		? Shale, marl, & marly limestone. Some beds sandy. ? Not identified	? Rudistid limestone ? Not identified	? Limestone, thick-bedded, contains many rudistids		? Escamela limestone
		? Limestone, thick-bedded & marly. Basal limestone breccia with gneiss & quartzite	? Limestone, thin-bedded. Lenses and beds of black chert.	? Limestone, thick-bedded, and calcareous shale ?	? Limestone, thick- to thin-bedded, in part interbedded with black chert	? Limestone, thick-bedded ?	? Limestone Rudistid limestone ?	? Cipiapa limestone ?	? Upper Maltrata limestone ? Necoxtla shale ?
		?	? Limestone and marl alternating	? Not identified	? Not identified	? Limestone	Not identified	? San Juan Raya formation	? Lower Maltrata limestone
? Tuxtla formation (Upper part of Todos Santos beds)	? Chinameca limestone	? Limestone, compact, gray ? Marly limestone and shale.	? Not identified	? Limestone dominant near top. Interbedded with shale, sandstone, and some coal.		? Interbedded shale, sandstone, & limestone. Thin-bedded limestone near top may equal lower part of Maltrata limestone.		? Zapotitlan formation Marl, shale, & limestone	? Not identified
JURASSIC	JURASSIC	JURASSIC						JURASSIC	



MEXICO
Huasteca area of eastern Hidalgo & northern Veracruz
Southern Oil fields of northern Veracruz
Northern Oil fields of south Tamaulipas & north Veracruz
Front Ranges west of Tampico
Cardenas-Canoas Tamasopo area of southeastern San Luis Potosi
West-Central San Luis Potosi
Southeastern Zacatecas
Fresnillo district of central Zacatecas
Sierra de Catorce of northern San Luis Potosi
Southwestern Tamaulipas and southernmost Nuevo Leon
Paleocene
Mendez shale
San Felipe formation
Agua Nueva formation
Tamaulipas limestone
Limestone, marl and shale
Limestone, compact
Marl and shale
El Abra limestone
Not identified
Upper Tamaulipas limestone
Lower Tamaulipas limestone
Limestone and chert
Limestone compact, white
Otates beds
Limestone, chalky
Limestone, coarsely crystalline and basal sandstone
Tamabra, or El Abra limestone
El Abra (miliolid) member
Taninul (rudistid) member
Cardenas formation
Tamasopo limestone
Rudistid limestone
Limestone & chert bands and nodules
Sandstone, shale shaly limestone
Limestone with intercalations of black chert
Limestone
Limestone compact
Taraises formation
Limestone & chert
El Abra member
Limestone, medium to thick-bedded
Limestone, thin-bedded to shaly
JURASSIC



Sierra de Tamaulipas of southeastern Tamaulipas
Paleocene
Mendez shale
San Felipe formation
Agua Nueva formation
Tamaulipas limestone
Limestone thin-bedded & lenses of black chert
Limestone thick-bedded
Otates beds
Not identified
Sierra de San Carlos of northern Tamaulipas
Paleocene
Mendez shale
San Felipe formation
Agua Nueva formation
Upper Tamaulipas limestone
Limestone thin-bedded & lenses of black chert
Limestone thick-bedded
Limestone thin-bedded
Lower Tamaulipas limestone
Limestone thick-bedded
Present(?)
JURASSIC(?)
Monterrey-Cienega del Toro-Saltillo area
Varicolored non-marine beds
Difunta formation
Parras shale
Indidura formation
Cuesta del Cura limestone
Aurora limestone
La Peña formation
Cupido limestone
Taraises formation (Las Cortinas formation)
JURASSIC
Concepcion del Oro-Mazapil-Melchor Ocampo north Zacatecas
Parras shale
Caracol formation
Indidura formation
Cuesta del Cura limestone
La Peña formation
Cupido limestone
Taraises formation
JURASSIC
Opal-Camacho area of northern Zacatecas
Varicolored sandstone alternating with gray shale and some beds of limestone. Upper age limit not known
Indidura formation
Cuesta del Cura limestone
Not identified
Sierra Ramirez and del Chivo, S.E. Durango & north Zacatecas
Not identified
Limestone, thin-bedded & chert
Parritas formation(?)
Taraises formation
JURASSIC
Middle Part Sierra de Parras & Parras Basin southern Coahuila
Difunta formation
Parras shale
Caracol formation
Indidura formation
Cuesta del Cura limestone
Aurora limestone
La Peña formation
Cupido limestone
Taraises formation
JURASSIC
Western Part Sierra de Parras & Parras Basin southern Coahuila
Difunta formation
Parras shale
Indidura formation
Cuesta del Cura limestone
Aurora limestone
La Peña formation
Parritas formation
Las Vigas fm.
Taraises formation
JURASSIC
Sierra de Jimulco of southwestern Coahuila
Cuesta del Cura limestone
Aurora limestone
La Peña formation
Las Vigas fm.
Taraises formation
JURASSIC
Sierra de Santa Ana of southwestern Coahuila
Indidura formation
Upper member
Middle member
Lower member
Aurora limestone
Upper Cuchillo fm.
Lower Cuchillo formation
Upper member
Lower member
PERMIAN



Sierra de La Peña of southwestern Coahuila
Indidura formation
Upper member
Middle member
Lower member
Aurora limestone
?
Not identified
Mountains west of Laguna District, eastern Durango
Indidura formation
Aurora limestone
?
La Peña formation
?
Parritas formation
?
Las Vigas fm.
Taraises formation
?
Carbonera formation
JURASSIC
Sierra del Rosario of eastern Durango
Indidura formation
Aurora limestone
?
La Peña formation
?
Probably exposed
San Pedro del Gallo of eastern Durango
?
Indidura formation
?
Cuesta del Cura limestone
?
La Peña formation
?
Parritas formation
Taraises formation
JURASSIC
Parral-Jimenez-Cañas area of southern Chihuahua
Not identified
?
Shale and thin beds of limestone
?
Present
?
Not identified
Sierra Mojada area of western Coahuila and S.E.Chihuahua
?
Soledad beds
?
Not identified
Indidura formation
?
Cuesta del Cura ls.
?
Aurora limestone
?
La Peña formation
Patula arkose(?)
?
Not exposed
Santa Elena area of eastern Chihuahua
?
Sandstone
?
Not identified
Shale and marl
Limestone and shale
Kiamichi fm.(?)
Aurora limestone
?
Cuchillo formation
Thin-bedded to shaly limestone and shale
?
Gypsum, shale and some limestone
?
Not exposed
Mountains of east-central Coahuila
?
Escondido formation
?
Mendez (Papagayos) shale
?
Shaly limestone and marl (San Juan limestone)
Indidura formation (Eagle Ford formation)
?
Cuesta del Cura limestone
?
Aurora limestone
La Peña fm.
Cuchillo formation
?
Patula arkose
?
La Mula shale
?
Padilla limestone
Barril viejo shale
San Marcos ark.
Menchaca ls.
?
Unnamed shale
?
Not identified
Northern Nuevo Leon & adjoining parts of Tamaulipas & Coahuila
?
Escondido formation
?
Olmos fm.
?
Tulillo beds
?
?
Mendez (Papagayos) shale
Austin chalk
(San Juan ls.)
Eagle Ford formation
?
Limestone, thin-bedded and marl
Kiamichi fm.(?)
Limestone, thick-bedded
?
Not exposed
San Ambrosio no.1 well near Camaron, north Nuevo Leon
?
San Miguel formation
?
"Papagayos" shale
?
"San Felipe" formation
"Agua Nueva" formation
?
Buda ls.
Del Rio shale
Limestone, hard dense
?
Shale and limestone interbedded
?
Limestone, hard, dense, brittle
?
Shale and limestone interbedded
?
Shale & some marly limestone
?
Limestone, hard, brittle
JURASSIC

MEXICO								
Area between Sierra del Burro and the Rio Grande	Sierra del Carmen area northwestern Coahuila	Santa Eulalia & San Pedro Conchos, central Chihuahua	Rio Conchos area of eastern Chihuahua	Cerro Muleros of northern Chihuahua	Arivechi area of eastern Sonora	El Tigre area of northeastern Sonora	Cabullona area of northeastern Sonora	EUROPEAN STAGES
Paleocene								
?	Not identified	Not identified	?				?	DANIAN
Escondido formation Olmos formation ?	Not identified	Not identified	Sandstone and conglomerate and shale				Cabullona group: Rhyolite tuff ? Redbeds ? Packard sh. ? Camas sandstone Snake Ridge formation ?	MAESTRICHTIAN
? San Miguel formation ? Upson clay ?	? Shale, marl and calcareous sandstone	Not identified	? Sandy shale, many beds of limestone					CAMPANIAN
? Austin chalk	? Chalky limestone, marl, and marly limestone	Not identified	? Sandy shale and marl					SANTONIAN
Austin chalk	Chalky limestone, marl, and marly limestone	Not identified	? Reddish sandstone and sandy shale					CONIACIAN
Eagle Ford formation (Boquillas flags) ?	? Platy limestone and shale (Boquillas flags)	? Marl and sandstone	? Ojinaga formation (Chispa Summit formation) ?	? Eagle Ford (Colorado) shale ?				TURONIAN
? Buda ls. Del Rio shale	? Limestone thick-bedded	? ? Limestone and marl	? Buda ls. Del Rio shale	Dakota s.s. ? Buda ls. Del Rio shale				CENOMANIAN
Georgetown limestone Kiamichi fm.(?) Edwards ls. ? Glen Rose limestone	Limestone thick-bedded	? Not identified	Aurora limestone ? Glen Rose limestone	Georgetown limestone equivalents Kiamichi fm. Edwards ls. Sandstone ?	Potrero fm. ? Palmar formation	? Limestone, shale, sandstone and a basal conglomerate	Bisbee group: ? Cintura fm. Mural limestone	ALBIAN
? Shaly limestone and shale ? Arkose in subsurface	? Shaly limestone and shale ? Red shale	Not identified	? Cuchillo formation	Not identified	? Not identified	Limestone, shale, sandstone and a basal conglomerate ?	Mural limestone Morita fm. Glance cong. ?	APTIAN
? Not exposed		Not identified	? Las Vigas formation	Not identified	Not identified			NEOCOMIAN: BARREMIAN
Not exposed			Las Vigas formation					NEOCOMIAN: HAUTERIVIAN
Not exposed			Las Vigas formation					NEOCOMIAN: VALANGINIAN
Not exposed			Las Vigas formation					NEOCOMIAN: BERRIASIAN
	MICA-SCHIST		JURASSIC			PERMIAN	PENNSYLVANIAN	

quence of coarse clastic and calcareous deposits is well shown in the Potrero de Menchaca of east-central Coahuila, in the western part of the Sierra de Parras of southern Coahuila, in the Sierras de Mapimí and Hispaña of eastern Durango, and apparently occurs in the lower part of the Conchos Valley of eastern Chihuahua, judged by Burrows'[3] description of the Las Vigas formation. The Neocomian sequence at these four localities may be compared as follows.

	Potrero de Menchaca	*Western Part of Sierra de Parras*	*Sierras de Mapimí and Hispaña*	*Lower Part of Conchos Valley*
Barremian	Padilla limestone	Parritas limestone	Parritas limestone, some sandstone, and shale	Las Vigas formation: Sandstone and shale with beds of limestone and gypsum near top
Hauterivian	Barril Viejo shale	Las Vigas sandstone and shale	Las Vigas sandstone and shale	Las Vigas formation (continued)
				——?——
Hauterivian	San Marcos arkose	Taraises formation: Marly limestone member	Taraises formation: Marly limestone member	Las Vigas formation: Shale
				——?——
Valanginian	Menchaca limestone	Taraises formation: Compact, hard, limestone member with a basal sandstone	Taraises formation: Compact, hard limestone member	Las Vigas formation: Calcareous sandstone
				——?——
Valanginian	Unnamed shale		Carbonera sandstone and shale	Las Vigas formation: Sandy limestone
	——?——			
Berriasian		Hiatus (?)	Hiatus (?)	Hiatus (?)

The offshore limestone and marl of Berriasian to Hauterivian age are remarkably similar over large areas. Throughout much of northern Mexico they are included in the Taraises formation which comprises a lower, compact limestone member of Berriasian to Valanginian age and an upper, marly limestone member of Hauterivian age. The Taraises formation has been recognized in eastern Durango, southern Coahuila, northern Zacatecas, western Nuevo León, and northern San Luis Potosí. It apparently was penetrated in the San Ambrosio well No. 1 near Cameron in northern Nuevo León. The limits of the Taraises formation are not known, but probably the formation is as extensive as the open-water deposits of the Neocomian sea and extends far beyond its known outcrops. Somewhat similar lower Neocomian limestone not showing a two-fold division has been identified near the city of San Luis Potosí in the southwestern part of the state, in three wells near Tampico, in the low hills south of Almanza in north-central Veracruz, near Parián and the city of Oaxaca in western Oaxaca, near Tehuacán in southeastern Puebla, and near Chinameca and Cerro Pelón in eastern

[3] R. H. Burrows, "Geology of Northern Mexico," *Bol. Soc. Geol. Mexicana*, T. 7 (1910), map, p. 93.

Veracruz. The thin-bedded to shaly limestones of lower Neocomian age in the area between Miquihuana in southwestern Tamaulipas and Galeana in south-central Nuevo León are sufficiently like the Taraises formation that they may be recognized by the same name even though some beds are sandy, or locally conglomeratic.

The Barremian is represented mainly by limestone that has furnished fossils at only a few places in Mexico, but whose age is indicated at many places by the underlying Hauterivian marly or sandy beds. In offshore areas it consists mainly of thick- to medium-bedded, gray limestone that is included in the Cupido limestone of northern Zacatecas, northern San Luis Potosí, southeastern Coahuila, and west-central Nuevo León; elsewhere it has not been named. In nearshore areas in northern Mexico it consists in many places of thin- to thick-bedded, yellowish, reddish, or gray limestone containing some intercalations of shale and sandstone, and locally some gypsum. Yellowish to reddish limestone and shale, called the Parritas formation, have been identified in the western part of the Sierra de Parras of southern Coahuila, in the Sierra del Chivo of northwestern Zacatecas, and in the mountains of east-central Durango between Torreón and San Pedro del Gallo. Gray, sandy, thick-bedded limestone, called the Padilla limestone, is characteristic of the Barremian of east-central Coahuila. Gypsiferous and calcareous beds at the top of the Las Vigas formation in the Placer de Guadelupe and Cuchillo Parado districts of eastern Chihuahua are probably Barremian in age. A nearshore facies is represented in the Tehuacán area of southeastern Pueblo by a considerable thickness of sandy to shaly marl, thin- to thick-bedded limestone, some limestone conglomerate, and sandstone, and locally rock salt and gypsum.

A detailed zonation of the Neocomian of Mexico and Central America can not be made with present information. The Berriasian is characterized by many species of *Spiticeras*, *Berriasella*, and *Subthurmannia*. *Himalayites*, *Neocosmoceras*, and *Protacanthodiscus* have been recorded but are uncommon. The lower Valanginian has not been identified faunally. The middle Valanginian is characterized by an abundance of *Thurmannites* typified by such giant forms as *T. miquihuanensis* Imlay and *T. novihispanicus* Imlay. The upper Valanginian is characterized by *Rogersites*, *Valanginites*, *Dichotomites*, *Kilianella*, and many species of *Olcostephanus*, although the genera have a greater range. *Polyptychites* and *Platylenticeras* have been recorded from the Valanginian but apparently are not common. The lower Hauterivian is characterized by many ammonites belonging to the genera *Olcostephanus*, *Maderia*, *Mexicanoceras*, *Acanthodiscus* (*s.s.*), *Leopoldia*, *Neocomites*, and *Distoloceras*. The upper Hauterivian has not been identified by distinctive fossils. Nearshore it must be represented by the unfossiliferous sandstones of the Las Vigas formation. Offshore it must be included in the highest beds of the upper member of the Taraises formation, or in the basal beds of the Parritas and Cupido limestones, but the only fossils found in these beds belong to the genera *Olcostephanus*, *Distoloceras*, *Bochiani-*

tes, *Leptoceras*, *Thurmannites*, and a questionable *Hemihoplites*. The Barremian is characterized by the ammonites *Pulchellia*, *Holcodiscus*, and *Barremites*. The lower Barremian may be recognized by the presence of *Pulchellia*, which in Europe ranges down into the upper Hauterivian, by the highest range of *Olcostephanus*, and by the lowest range of *Pseudohaploceras*. The upper Barremian may be recognized by forms of *Holcodiscus* and *Barremites* in association with *Costidiscus* and abundant *Pseudohaploceras*.

APTIAN, ALBIAN, AND LOWER CENOMANIAN

The Mexican sea during the lower Aptian was apparently nearly as restricted as during the Neocomian, but during the upper Aptian it spread northward over the Coahuila Peninsula into the area of Texas and westward as far as eastern Sonora (Fig. 3). A narrow arm of the sea extended westward along the site of the international boundary at least as far as the area of the Patagonia Mountains, about 50 miles west of Bisbee, Arizona. A sea of Aptian age was widespread in southern Mexico, but its limits are not known. Submergence became even more widespread during the Albian. In southern Mexico and Central America the Albian and lower Cenomanian sea lapped against a granitic and gneissic mass marking the southern margins of Guerrero, Oaxaca, Chiapas, Guatemala, San Salvador, and Honduras. Possibly the sea extended south of this granitic mass in Central America, but no fossil evidence of such extension is known. Extension of the Albian sea across southern Mexico as far west as the present Pacific coast strongly suggests that a marine connection existed with the Albian sea of Baja California.[4] Considerable evidence for the development of an angular unconformity in southern Mexico during lower and middle Albian time has been presented by Burckhardt,[5] but Mullerried[6] has questioned its existence. An unconformity near the boundary of the Lower and Upper Cretaceous has not been recorded south of San Luis Potosí, but north of there a major change in sedimentation occurred in lower Cenomanian time, apparently coinciding with the unconformity between the Comanche and Gulf series in the southern United States. Although a definite unconformity of this age can be demonstrated at only a few places in northern and eastern Mexico, the slight thickness of beds that can be assigned to the Cenomanian suggests that most parts of the sea floor were raised to or above the base level of deposition for a considerable time.

Lower Aptian has been identified faunally at only a few places, but its presence over large areas is indicated by the overlying, fossiliferous, upper Aptian. Throughout most of its extent the lower Aptian is represented by gray, hard,

[4] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 211.

[5] *Ibid.*, pp. 157–62, 196, 200–05.

[6] F. K. G. Mullerried, "Estudios paleontológicos y estratigráficos en la región de Tehuancán, Puebla," *Anales Inst. Biología México*, T. 5, No. 1 (1934), p. 73.

———, "The Mesozoic of Mexico and Northwestern Central America," *Proc. Eighth Amer. Scientific Congress*, Vol. 4 (1942a), p. 135.

FIG. 3.—Aptian-Albian fossil localities in Central America and Mexico.

compact, thick- to medium-bedded limestone that in eastern Mexico is included in the lower Tamaulipas limestone and in north-central Mexico generally in the upper part of the Cupido limestone. In the Sierras de Parras, Jimulco, Hispaña, and Mapimí bordering the site of the Coahuila Peninsula, the lower Aptian limestone contains considerable shaly material and is included in the lower part of the La Peña formation. A nearshore facies, which is present on the very margin of the peninsula, consists in some places of interbedded gypsum and limestone and in near-by places of arkose and varicolored shale. Arkosic sediments underlying upper Aptian beds crop out in the mountains of east-central Coahuila, in the Sierra Mojada of easternmost Chihuahua, and were penetrated in wells in northern Coahuila near Del Rio, Texas. Varicolored shale at the same stratigraphic position crops out in the Sierra del Carmen area of northwestern Coahuila and in the Potrero de la Mula of east-central Coahuila. A thick gypsiferous facies occurs in the Cuchilla Parado, Placer de Guadalupe, and Santa Elena districts of eastern Chihuahua. At Cuchillo Parado salt is associated with the gypsum. A nearshore facies of marl, sandstone, and conglomerate is represented by the lower part of the San Juan Raya formation in the Tehuacán area of southeastern Puebla. The few ammonites recorded from the lower Aptian bed belong to *Pseudohaploceras*, *Costidiscus*, *Melchiorites*, and the Ancyloceratidae.

The upper Aptian and basal Albian are represented by a widespread, thin unit of shaly to thin-bedded limestone that in eastern Mexico has been called the Otates beds and in north-central Mexico has been included in the La Peña or Cuchillo formations. It ranges from 50 to 500 feet in thickness, averaging perhaps 100 feet, and has been identified at many places in eastern Chihuahua, eastern Durango, northern Zacatecas, northern San Luis Potosí, northern Veracruz, southern Tamaulipas, and in nearly all parts of Nuevo León and Coahuila. In the central parts of the Mexican geosyncline near Mazapil, Zacatecas, and near San Pedro del Gallo, Durango, the shale and thin-bedded limestone of the La Peña formation contain interbeds of black chert. Similar chert-bearing limestone and shale of upper Aptian age occur in the Orizaba area of central Veracruz. The possible extension of similar beds in southern Mexico is indicated by the occurrence of shales containing *Dufrenoya* near Campo Morado in northern Guerrero.

An upper Aptian nearshore facies called the San Juan Raya formation occurs in the Tehuacán-San Juan Raya area of southeastern Puebla. It consists of shale, marl, thin-bedded limestone, sandstone, some conglomerate, and locally includes beds of salt and gypsum. It may be taken as evidence of a peninsular landmass to the south in east-central Oaxaca at least during Aptian time. Near Las Delicias, Coahuila, the upper Aptian and basal Albian are represented by 50 to 100 feet of shaly to sandy limestone interbedded with shale, sandstone, and conglomerate that rests on Permian. The thickest and coarsest nearshore deposits of upper Aptian-basal Albian age that are known in Mexico are in eastern

and northern Sonora, where they are included in the lower part of the Bisbee group. Possibly similar coarse deposits will be found along the western margin of the Mexican geosyncline in western Chihuahua and Durango when those areas are explored.

Characteristic upper Aptian ammonites in Mexico include *Dufrenoya, Cheloniceras, Procheloniceras, Pedioceras, Ammonitoceras,* and *Pseudohaploceras. Cheloniceras* ranges into the lower Albian but is uncommon above the Aptian. *Pseudohaploceras* ranges down into the Barremian. It is generally assumed that the beds characterized by *Dufrenoya* are equivalent to the upper half of the Aptian of the European sequence, but actually these beds may be equivalent to a much smaller part of the Aptian. Characteristic basal Albian ammonites include species of *Douvilléiceras* similar to *D. nodosocostatum* D'Orbigny. Beds containing an abundance of *Hypacanthoplites* and *Acanthoplites* not associated with *Dufrenoya, Cheloniceras,* or *Pseudohaploceras* are likely to be early Albian in age.

The middle Albian and the upper part of the lower Albian in Mexico are represented by several distinct facies. One of the most characteristic facies consists of rudistid limestone, generally of considerable thickness, that was deposited over areas that were landmasses in Upper Jurassic or Neocomian time, or that were adjacent to landmasses. The rudistid limestone has been variously called the Edwards, Finlay, Aurora, and El Abra limestones. The name Edwards has been applied to beds of late middle Albian age in the Sierra del Burro of northern Coahuila, and the name Finlay to equivalent beds in the Cerro Muleros of northern Chihuahua. The beds so called appear to be exactly equivalent to the Edwards limestone of Texas. The name Aurora has been defined for rudistid limestone of middle to upper Albian age in the Cuchillo Parado and Placer de Guadalupe districts of eastern Chihuahua and may be identical with the Devils River limestone of Valverde County, Texas. Farther south and east the name Aurora has been applied to beds of middle Albian and late lower Albian age. The Aurora limestone, thus defined, terminates on the south in the Sierras de Parras and Jimulco of southern Coahuila, on the west in the Sierra de San Francisco just east of San Pedro del Gallo, on the east in the Sierra Azul of eastern Coahuila and the Sierra de Bustamante of western Nuevo León. A strip of rudistid limestone identical with the Aurora limestone is apparently continuous along the Sierra Madre Oriental from the region of Saltillo southward to southwestern Tamaulipas, where it merges with the El Abra, or Tamabra, limestone. The El Abra has been identified in the front ranges west of Tampico from the vicinity of Gomez Farias southward to Tamazunchale and likewise underlies the southern oil fields near Túxpan, in northern Veracruz. Most of the rudistids occur in the Taninúl member, which is probably equivalent to the Aurora limestone of Coahuila. Thick rudistid-bearing limestone of middle Albian age occurs likewise near Ixmiquilpán in western Hidalgo, near Atliaca in east-central Guerrero, near

Metapán in El Salvador, and at many places in Honduras and northern Guatemala. Perhaps some of the rudistid-bearing limestone in southern Chiapas and Oaxaca are of the same age, but fossil evidence is lacking.

A second facies of middle Albian and late lower Albian age that was deposited in the central parts of the Mexican geosyncline, and is probably as extensive as the rudistid-bearing Aurora and El Abra limestones, consists of interbeds of dense, generally thin-bedded limestone and black chert. This cherty facies in north-central Mexico is included in the lower part of the Cuesta del Cura limestone and may be distinguished from the upper part of the same formation by being less wavy-bedded and by containing units of medium-bedded limestone. The basinward change from the thick Aurora limestone to the lower part of the much thinner Cuesta del Cura limestone takes place within a few miles in the Sierra de Parras, showing that the rudistid reefs terminated rather abruptly on their seaward side.

A third facies of middle Albian and late lower Albian age consists of dark, dense, medium- to thick-bedded limestone containing highly ornamented ammonites and is widespread in eastern Mexico east of the rudistid-bearing Aurora limestone. It occurs (1) in the easternmost front of the Sierra Madre Oriental from Lampazos in northern Nuevo León to Victoria in southwestern Tamaulipas, (2) in the Sierras de San Carlos and Tamaulipas of Tamaulipas, and (3) in the northern oil fields near Tampico. Throughout most of this area it includes that part of the Tamaulipas limestone above the Otates beds and below the thin-bedded limestone and black chert of upper Albian age. However, in the Sierra de Lampazos of northern Nuevo León, it is overlain by formations comparable with the Kiamichi and Georgetown formations of Texas.

A fourth facies of middle Albian to late lower Albian age consists of interbedded limestone and marl characterized by *Orbitolina texana* (Roemer). It is represented (1) by the thick Glen Rose limestone in the Sierra del Burro of northern Coahuila, (2) by the thin Glen Rose limestone (?) at the base of the Aurora limestone in the Cuchillo Parado district of eastern Chihuahua, (3) by the upper member of the Mural limestone of the Cabullona area of northern Sonora, (4) by the upper member of the lower Cuchillo formation of the Sierra de Santa Ana near Las Delicias, Coahuila, (5) by the lower part of the El Abra limestone near Miquihuana, Tamaulipas, and in the southern oil fields of northern Veracruz, (6) by unnamed beds in Colima, southern Jalisco and east-central Guerrero, and (7) by part of the Cobán formation, or equivalent beds, in El Salvador, Honduras, and Guatemala. In most places this *Orbitolina*-bearing facies is overlain by rudistid-bearing limestone, or nearshore clastic deposits of late middle Albian age, and it was deposited over areas that were landmasses in Upper Jurassic time, or were only slightly submerged and adjacent to landmasses.

A fifth facies of middle Albian and late lower Albian age in the area of the Coahuila Peninsula of western Coahuila consists of interbedded limestone,

dolomite, and gypsum of considerable thickness, and is included in the upper part of the Cuchillo formation. Its stratigraphic position is approximately the same as that of the Ferry Lake anhydrite of the Arkansas-Louisiana-East Texas area.

A sixth facies of the same age, represented by the Potrero and Palmar formations of east-central Sonora, consists of interbedded limestone, shale, agglomerate, and lava of great thickness and may be expected to have a considerable distribution along the western margin of the Mexican geosyncline.

A seventh facies consists of marl and thin-bedded limestone, is characterized by the ammonite *Oxytropidoceras*, occupies the same stratigraphic position as the Kiamichi shale of Texas, is widespread in northern Nuevo León, northern Coahuila, and eastern Chihuahua, and probably represents only the late middle Albian.

The characteristic fossils of the middle Albian and late lower Albian of Mexico and Central America are the same as are known in equivalent beds in Texas, but in general are poorly preserved or uncommon. *Toucasia texana* (Roemer), *T. patagiata* (White), and *Orbitolina texana* (Roemer) characterize the reef limestones. *Sonneratia* of lower Albian age has been recorded only from the Valle de Muralla in east-central Coahuila.[7] *Lyelliceras* of late lower or middle Albian age has been recorded from the Sierra de Tamaulipas in southern Tamaulipas, and near Opal in northern Zacatecas. *Oxytropidoceras*, an excellent middle Albian marker, has been recorded from many localities. *Inoceramus subsulcatiformis* Böse has been identified in Mexico only in the Sierra de San Carlos of Tamaulipas.

The upper Albian and lower Cenomanian are represented by several facies. Rudistid-bearing limestone of upper Albian age is represented (1) by the upper part of the Aurora limestone in the Cuchillo Parado and Placer de Guadalupe districts of eastern Chihuahua, and (2) by the equivalent Devils River limestone of northwestern Coahuila and the adjoining parts of Texas near Del Rio. These formations are overlain by the Del Río shale and Buda limestone, which are generally considered to be of lower Cenomanian age. Miliolid-bearing limestone containing some rudistids and apparently of upper Albian to lower Cenomanian age occurs in the upper part of the El Abra limestone of the southern oil fields near Túxpan, Veracruz, and of the front ranges west of Tampico between Gomez Garias and Tamazunchale. Similar upper Albian limestone apparently occurs in southern Mexico bordering a granitic mass along the Pacific Coast but little information concerning this limestone has been published.

A second facies mainly of upper Albian age is represented by highly fossiliferous, thin-bedded limestone and marl comparable in many respects with the Georgetown limestone of Texas. It has been identified in the Sierra del Burro of northern Coahuila, the Sierra de Lampazos of northern Nuevo León, the Cerro

[7] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 145, 146.

Muleros of northern Chihuahua, the Santa Elena area of easternmost Chihuahua, and the Sierra de Santa Ana near Las Delicias, Coahuila. At the last mentioned locality it has been called the lower member of the Indidura formation and represents both the upper Albian and the lower Cenomanian. At these localities it overlies areas that were landmasses, or marginal to landmasses, in Upper Jurassic time.

A third facies of upper Albian to lower Cenomanian age consists of wavy-bedded, thin-bedded limestone, and many lenses of black chert. It is represented by the Cuesta del Cura limestone of north-central Mexico, by the upper member of the Tamaulipas limestone of eastern Mexico, and by the upper Maltrata limestone of west-central Veracruz. It is one of the most persistent and widespread facies in Mexico, having been identified in all the northern states east of Sonora and in the southern states of Colima, Jalisco, and Veracruz. It is apparently coextensive with the offshore, deeper water portion of the Mexican sea and was considered by Böse and Cavins[8] to represent bathyal, or deep water deposits. It grades shoreward, or in areas that were shallowly submerged, into marl and limestone of Georgetown limestone facies, or into rudistid-miliolid limestone of the El Abra-Aurora limestone facies.

The lower Cenomanian age of the highest part of the El Abra limestone is indicated by the occurrence of *Pecten* (*Neithea*) *roemeri* Hill in limestone underlying the Agua Nueva formation at Riachuelos and near Rascón in eastern San Luis Potosí, and from two wells in the southern oil fields of Veracruz.[9] The upper Albian age of most of the upper miliolid member of the El Abra formation is shown by the occurrence of the middle Albian species, *Toucasia texana* (Roemer), in the underlying Taninúl member.

The marl and thin-bedded limestone facies similar to the Georgetown limestone contains species of *Pervinquieria* and *Prohysteroceras* identical with those in the Georgetown limestone. The uppermost beds of this facies in the Santa Elena district of eastern Chihuahua contain *Stoliczkaia* similar to *S. texana* (Cragin) which suggests a lower Cenomanian age. The lower member of the Indidura formation in the Sierra de Santa Ana of southwestern Coahuila contains oysters characteristic of the Washita and at the top contains the Cenomanian genus *Mantelliceras*. In the Sierra del Burro of northern Coahuila and the Cerro Muleros of northern Chihuahua the Georgetown limestone, or equivalents, is overlain by the Del Río and Buda limestones containing lower Cenomanian fossils.

Fossils are uncommon in the Cuesta del Cura limestone facies. Böse and Cavins[10] considered that part of the middle Albian, including at least the equiva-

[8] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2728* (1927), pp. 89, 90.

[9] John M. Muir, *Geology of the Tampico Region, Mexico*, Amer. Assoc. Petrol. Geol. (1936), pp. 39, 41.

[10] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), pp. 23, 24.

lents of the Kiamichi formation of Texas, was represented in the basal part of the Cuesta del Cura limestone, but this has been proved only for the areas near Mazapil and Camacho in northern Zacatecas and near San Pedro del Gallo in eastern Durango, which are in the central part of the Mexican geosyncline. Upper Albian forms of *Pervinquieria*, *Hysteroceras*, and many uncoiled ammonites have been recorded near Mazapil, Camacho, Noria de Angeles, and Fresnillo in Zacatecas and in the Sierra de Catorce of northern San Luis Potosí. Some of the uncoiled ammonites have been found near San Pedro del Gallo in eastern Durango, in the Sierra de la Paile of southeastern Coahuila, and near Aramberri in Nuevo León. *Pervinquieria* has been recorded near the city of Colima in southwestern Mexico. Cenomanian forms of *Turrilites* and *Scaphites* have been recorded near Mazapil and Camacho in northern Zacatecas.

UPPER CENOMANIAN AND TURONIAN

A slight restriction of the Mexican sea at the end of the lower Cenomanian, as indicated by unconformities in marginal areas in Chihuahua and Coahuila, was soon followed by a readvance over approximately the same area covered by the sea during Albian time. The presence of fine-grained sandstone in the upper Cenomanian-Turonian beds of southeastern Zacatecas and south-central and north-central Chihuahua suggests that the sea may not have extended as far west as during Albian times, when rudistid- and chert-bearing limestones were deposited in the same areas. Likewise, the presence of sandy marl interbedded with sandstone at the top of the Turonian of west-central Chiapas and the sandy shale and marl at the top of the Turonian near Zumpango del Río, Guerrero, suggests that the landmass in southern Mexico was beginning to rise and to restrict the sea somewhat. The presence of rudistid-bearing limestone of Cenomanian and Turonian age in Colima near the Pacific Coast suggests but does not prove that the Mexican sea was connected with the Pacific Ocean.

The upper Cenomanian and Turonian (Fig. 4) are represented by five distinct facies. A rudistid facies predominates in southern Mexico as far north as central Hidalgo and Querétaro. In Chiapas it is included in the upper part of the Cobán limestone, as currently defined, and in west-central Veracruz is included in the Escamela limestone. Similar rudistid-bearing limestone in Colima, Jalisco, Michoacán, México, Morelos, Puebla, Hidalgo, Querétaro, and southwestern San Luis Potosí has not been named. Among the many rudistids assigned to the Cenomanian some of the most common are *Coalcomana ramosa* (G. Boehm), *Monopleura* (*Petalodontia*) *calamitiformis* Bárcena, *Caprinuloidea? felixi* (G. Boehm), and *C.? lenki* (G. Boehm). The citation[11] of *Coalcomana ramosa* from Ixmiquilpán, Hidalgo, in association with definite middle Albian fossils may be significant, as it is normally associated with rudistids very distinct from those in the Edwards limestone of Texas. Either the species of *Coalcomana* has a long

[11] F. K. G. Mullerried, "Apuntes paleontológicos y estratigráficos sobre el Valle del Mezquital, Estado de Hidalgo," *Anales Escuela Nac. Cien. Biologicas*, Vol. 1, Núm. 2 (1939b), Pls. 40–43, pp. 225–54.

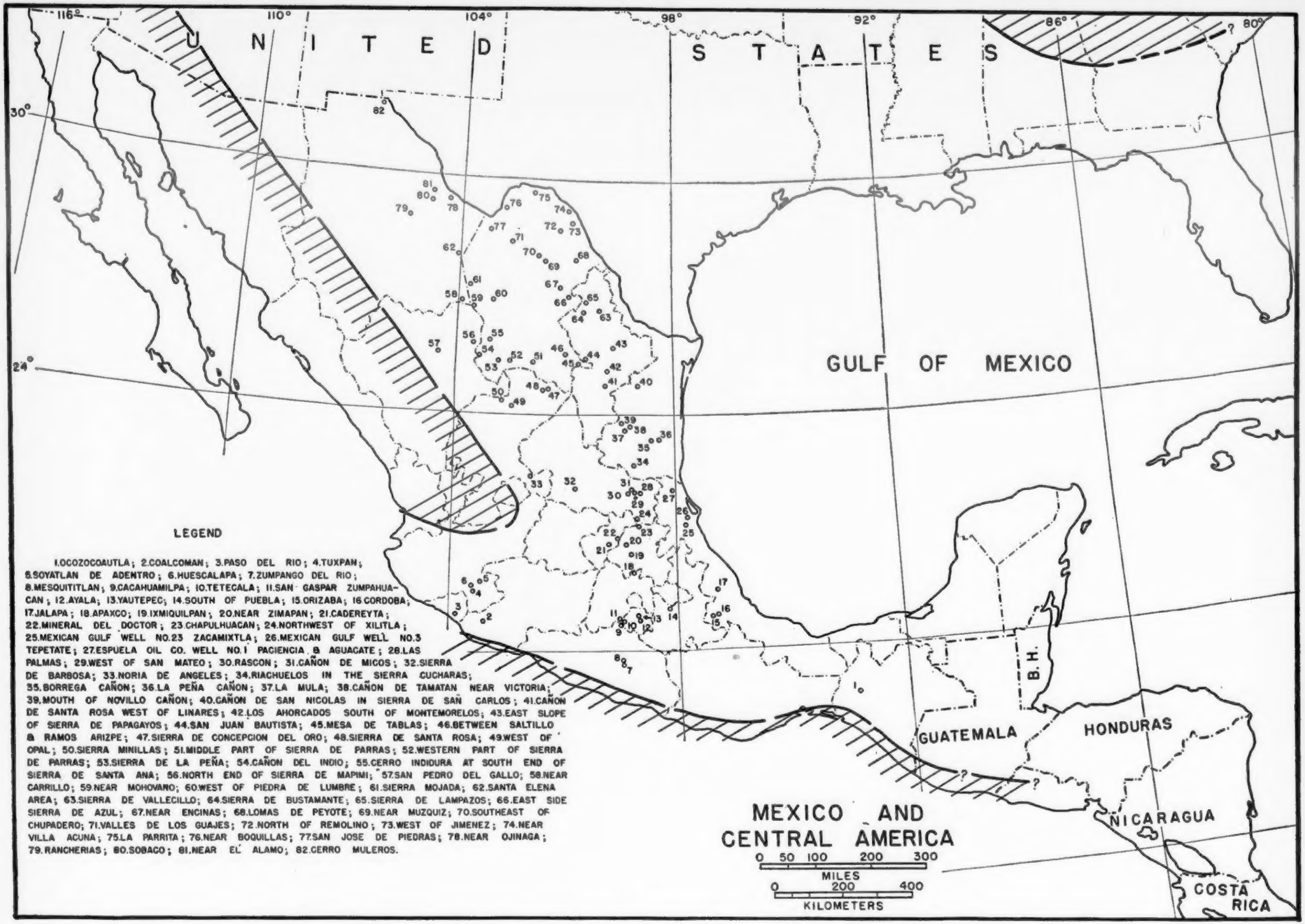


FIG. 4.—Cenomanian-Turonian fossil localities in Central America and Mexico.

FIG. 4.—Cenomanian-Turonian fossil localities in Central America and Mexico.

range, or the so-called Cenomanian beds are actually Albian, or there are several closely related species that are difficult to distinguish from one another. The citation of *Orbitolina* from the Escamela limestone is also of interest as the genus has not been reported above the middle Albian in the southern United States, or in northern South America. The most frequently cited rudistids representing the Turonian include *Biradiolites lombricalis* D'Orbigny, *Apricardia chavesi* Palmer, *Tepeyacia corrugata* Palmer, and *Hippurites mexicanus* Bárcena. These species, with the possible exception of *Tepeyacia corrugata*, appear to be upper Turonian in age.

Throughout much of northern and eastern Mexico the upper Cenomanian and Turonian are represented by alternating beds of dark, thinly laminated, platy limestone, shaly limestone, and shale which in northernmost Coahuila and Nuevo León are recognized as the Boquillas flag facies of the Eagle Ford formation; in Nuevo León, Tamaulipas, eastern San Luis Potosí, and northern Veracruz are called the Agua Nueva formation; and in eastern Durango, southernmost Coahuila, Zacatecas, eastern Coahuila, and west-central Nuevo León are recognized as an offshore facies of the Indidura formation. This facies is probably the most uniform and widespread of any in Mexico. It has furnished very few fossils other than *Inoceramus labiatus* (Schlotheim), *I. hercynicus* Petrascheck, and fish scales. However, a Cenomanian ammonite, *Mantelliceras* aff. *M. couloni* (D'Orbigny) was found 10 feet above the base of the Agua Nueva formation in a road cut 18 kilometers southwest of Tamazunchale,[12] and *Prionotropis woolgari* var. *mexicana* Böse was found in the upper part of the Boquillas flags near Villa Acuña in northern Coahuila.

A third facies of upper Cenomanian-Turonian age consists of fairly thick, highly fossiliferous shale and marl and has been identified in the Sierra Mojada, the Santa Elena area, and the lower part of the Conchos Valley of eastern Chihuahua, and in western Jeff Davis County, Texas. The facies in Texas has been named the Chispa Summit formation, and in the Conchos Valley has been named the Ojinaga formation. It is characterized by an abundant ammonite fauna that has been discussed by Adkins[13] and that is indicated on the accompanying correlation chart (Table I). Similar beds of lower and upper Turonian age occur near Zumpango del Río in east-central Guerrero.

A fourth facies consists of thin, highly fossiliferous shale and nodular to platy limestone, is included in the middle and upper members of the typical Indidura formation and has been identified in west-central and southwestern Coahuila in the Sierra de Santa Ana, the Sierra de la Peña, near Piedra de Lumbre, and on Cerro del Macho near Mohóvano. These areas are on or marginal to the site of the Coahuila Peninsula. The facies is characterized by many pelecypods,

[12] John M. Muir, *Geology of the Tampico Region, Mexico*, Amer. Assoc. Petrol. Geol. (1936), p. 53.

[13] W. S. Adkins, "The Mesozoic Systems in Texas" in "The Geology of Texas," Vol. 1, Stratigraphy, *Univ. Texas Bull. 3232*, Pt. 2 (1933), p. 437.

echinoids, and ammonites, and probably was deposited slowly in very shallow waters. The lower Turonian is represented by *Vascoceras*, *Neoptychites*, *Mammites*, *Fagesia*, *Metoicoceras* aff. *M. whitei* Hyatt, and *Exogyra* aff. *E. olisiponensis* Sharpe. The upper Turonian is represented by *Romaniceras*, *Prionotropis* and *Coilopoceras*. *Inoceramus labiatus* (Schlotheim) occurs throughout the facies.

A fifth facies consists of fine-grained sandstone interbedded with shale and limestone and has been identified in the Cerro Muleros in northern Chihuahua, in the Sierra de Villalba south of San Pedro Concho in south-central Chihuahua, near Noria de Angeles in southeastern Zacatecas, near Ocozocoautla in west-central Chiapas, and near Zumpango del Río in east-central Guerrero.

CONIACIAN AND SANTONIAN

The Mexican sea of Coniacian and Santonian time (Fig. 5) was considerably more restricted than during the Turonian, although its boundaries, on the basis of available information, can only be roughly indicated. An unconformity at the end of Turonian time was developed locally in the front ranges west of Tampico, but elsewhere has not been noted. Landmasses in western Mexico were rising rapidly as shown (1) by a fairly thick section of sandstone and sandy shale in the Ojinaga area of northeastern Chihuahua and (2) by over 5,000 feet of shale with some sandstone and considerable volcanic tuff in the Parras Basin of southern Coahuila and in northern Zacatecas at least as far south as Mazapil and Opal. Beds of this age have not been identified in western San Luis Potosí, but the presence of the thick, rudistid-bearing Tamasopo limestone in eastern San Luis Potosí suggests deposition on a shallowly submerged platform projecting eastward from a landmass. Landmasses were probably rising slowly in the Pacific Coast area of southernmost Mexico as reflected by the presence of some sandy beds of Coniacian and Santonian age near Zumpango del Río in east-central Guerrero and near Ocozocoautla in west-central Chiapas. The westward extent of the sea in southern Mexico is not known, but there is no faunal evidence of a connection with the Pacific Ocean.

Probably the most widespread facies of the Coniacian-Santonian consists of thick shale containing minor amounts of sandstone and locally large amounts of volcanic tuff. The northernmost known occurrence of this facies in Mexico is in the Ojinaga area of northeastern Chihuahua where the Coniacian is represented by reddish sandstone and sandy shale, and the Santonian by sandy shale and marl. A little farther north in western Jeff Davis County, Texas, equivalent beds consist of about 1,200 feet of clay named the Colquitt formation by Adkins.[14] Equivalent beds probably exist in eastern Chihuahua but have not been studied.

The best known occurrence of this shale facies is in southern Coahuila, near Parras, where the Coniacian is represented in part by 100 feet of shaly to thin-bedded limestone, that for convenience has been included in the upper part of

[14] W. S. Adkins, "The Mesozoic Systems in Texas" in "The Geology of Texas," Vol. 1, Stratigraphy, *Univ. Texas Bull. 3232*, Pt. 2 (1933), p. 452.

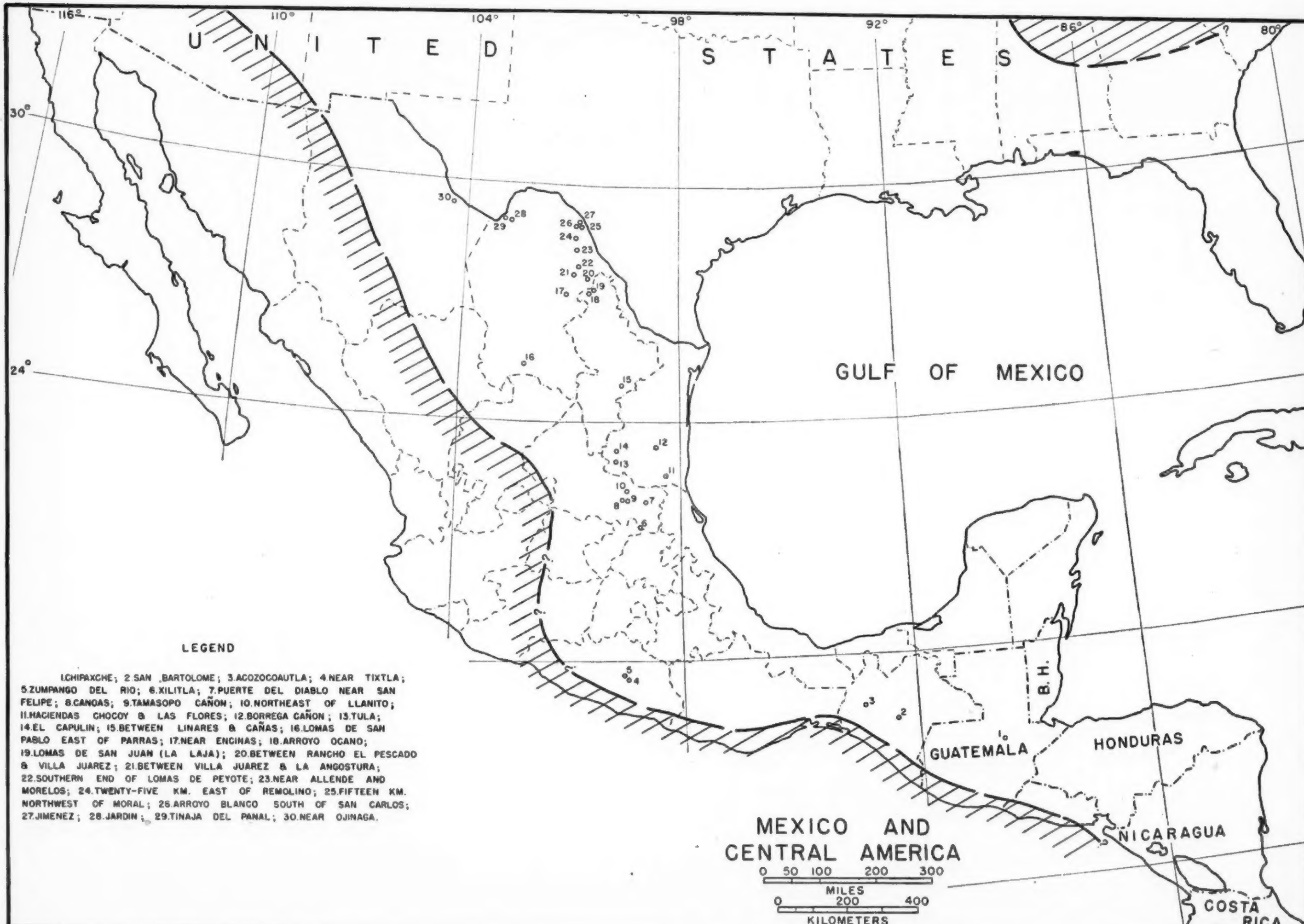


FIG. 5.—Coniacian-Santonian fossil localities in Central America and Mexico.

the Indidura formation, and the remainder of the Coniacian and Santonian is represented by about 5,000 feet of Parras shale. Eastward from Parras the shaly to thin-bedded limestone of Coniacian age passes into thicker tuffaceous beds, called the Caracol formation, which has been identified as far south as Mazapil and attains a thickness of about 3,350 feet near Melchor Ocampo in northern Zacatecas. A great thickness of varicolored sandstone and shale cropping out south of Opal in northern Zacatecas, about 75 miles southwest of Mazapil, probably includes the Caracol formation. The Parras shale has been traced as far south as Melchor Ocampo, passes northward into the Austin chalk in east-central Coahuila, and extends eastward across southern Coahuila to the area between Saltillo and Monterrey, in west-central Nuevo León. Equivalent calcareous shale occurring in eastern Nuevo León and northern Tamaulipas is included in the lower part of the Méndez (Papagayos) shale, which part passes northwestward into the much thinner Austin chalk and southward into the much thinner San Felipe limestone. Thus the distribution of the Caracol formation and Parras shale and the equivalent part of the Méndez shale in northern Tamaulipas and eastern Nuevo León shows that the source of the clay and sand was to the west in Durango or southwestern Zacatecas and that deposition occurred in a rapidly subsiding trough trending eastward across southern Coahuila and northern Zacatecas into central Nuevo León.

The landmass bordering the Mexican sea on the south does not appear to have furnished much coarse sediment during Coniacian and Santonian time. Some shale and limestone, in part sandy, and containing ammonites, gastropods, Inocerami, and plant remains of Coniacian age, occur near Zumpango del Río in east-central Guerrero. About 10 miles southeast, near Tixtla, the Santonian is represented by interbedded sandstone and limestone containing rudistids and other pelecypods. Sandy beds of Coniacian age occur near Ocozocoautla in western Chiapas.

A second facies of Coniacian and Santonian age is represented by about 1,300 feet of chalky, marly, and shaly limestone in northern Coahuila and northwestern Nuevo León. It was named the San Juan limestone by Dumble[15] but is more generally and satisfactorily called the Austin chalk. It grades southward in Coahuila, south of Cuatro Ciénegas and Monclova, into the much thicker Parras shale and the upper part of the Indidura formation of offshore facies.[16] It grades eastward in eastern Nuevo León and northern Tamaulipas into the lower part of the Méndez (Papagayos) shale.

A third facies, very similar to the Austin chalk, occurs in eastern Mexico from the Sierra de San Carlos, Tamaulipas, on the north to the Poza Rica fields of northern Veracruz on the south and also in the front ranges west of Tampico.

[15] E. T. Dumble, "Tertiary Deposits of Northeastern Mexico," *Proc. California Acad. Sci.*, Vol. 5, No. 6 (1915), p. 170.

[16] R. W. Imlay, "Geology of the Western Part of the Sierra de Parras," *Bull. Geol. Soc. America*, Vol. 47 (1936), pp. 1132, 1133.

It is represented by 500 to 1,300 feet of gray, generally thin-bedded limestone containing small amounts of shale, that becomes more common toward the top, and some beds of bentonite. It is generally called the San Felipe formation, although a chalky portion in the Sierra de Tamaulipas was named the Solis limestone by Böse and Cavins.[17] It grades westward from the Sierra de San Carlos into the lower part of the Méndez (Papagayos) shale of the Montemorelos-Linares area of east-central Nuevo León. It grades westward from the front ranges of easternmost San Luis Potosí into the thick, rudistid-bearing Tamasopo limestone.

A fourth facies is represented by rudistid-bearing limestone that is fairly common in Chiapas and northern Guatemala, according to Mullerried,[18] and includes the Tamasopo limestone of eastern San Luis Potosí. The Tamasopo limestone consists mainly of thick-bedded, dense, brittle, light-buff limestone, but contains some shale layers, particularly near its top, and is estimated to be between 3,300 and 6,560 feet thick. It grades northward into the San Felipe formation near El Capulín in southwestern Tamaulipas. It grades eastward into the San Felipe and the upper part of the Agua Nueva formations near Rascón and Llanito in eastern San Luis Potosí. Its western and southern extensions are unknown.

According to Burckhardt[19] the Coniacian of Mexico is characterized by *Peroniceras, Gauthiericeras* cf. *G. margae* (Schlüter), *Barroisiceras* aff. *B. haberellneri* (Hauer), and giant Inocerami related to *Inoceramus undulatoplicatus* Roemer. The Santonian is characterized by *Texanites texanum* (Roemer), *Canadoceras flaccidicostum* (Roemer), *Baculites,* and large Inocerami. The rudistids are completely unknown. The age of the Tamasopo limestone is determined by its position beneath the Méndez shale, which is marked basally by a conglomerate, and by its lateral gradation into the San Felipe and Agua Nueva formations. The age of the San Felipe limestone is determined by its stratigraphic position above beds of Turonian age and by containing in the upper part pelecypods that furnish a correlation with the upper part of the Austin chalk. The age of the Parras shale is determined by its stratigraphic position below the Difunta formation that contains fossils of Taylor age and above a thin unit of shaly to thin-bedded limestone that contains *Peroniceras* of probable lower Coniacian age.

CAMPANIAN AND MAESTRICHTIAN

The Mexican sea of Campanian and Maestrichtian time (Fig. 6) was considerably more restricted than earlier in the Upper Cretaceous, as shown by the occurrence of coarse conglomerate and coal beds in eastern Chihuahua and fine

[17] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), p. 70.

[18] F. K. G. Mullerried, "Estratigraffa preterciaria preliminar del Estado de Chiapas," *Bol. Soc. Geol. Mexicana,* T. 9 (1936), pp. 38, 39.

[19] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.,* Vols. 49, 50 (1930), pp. 225–27.

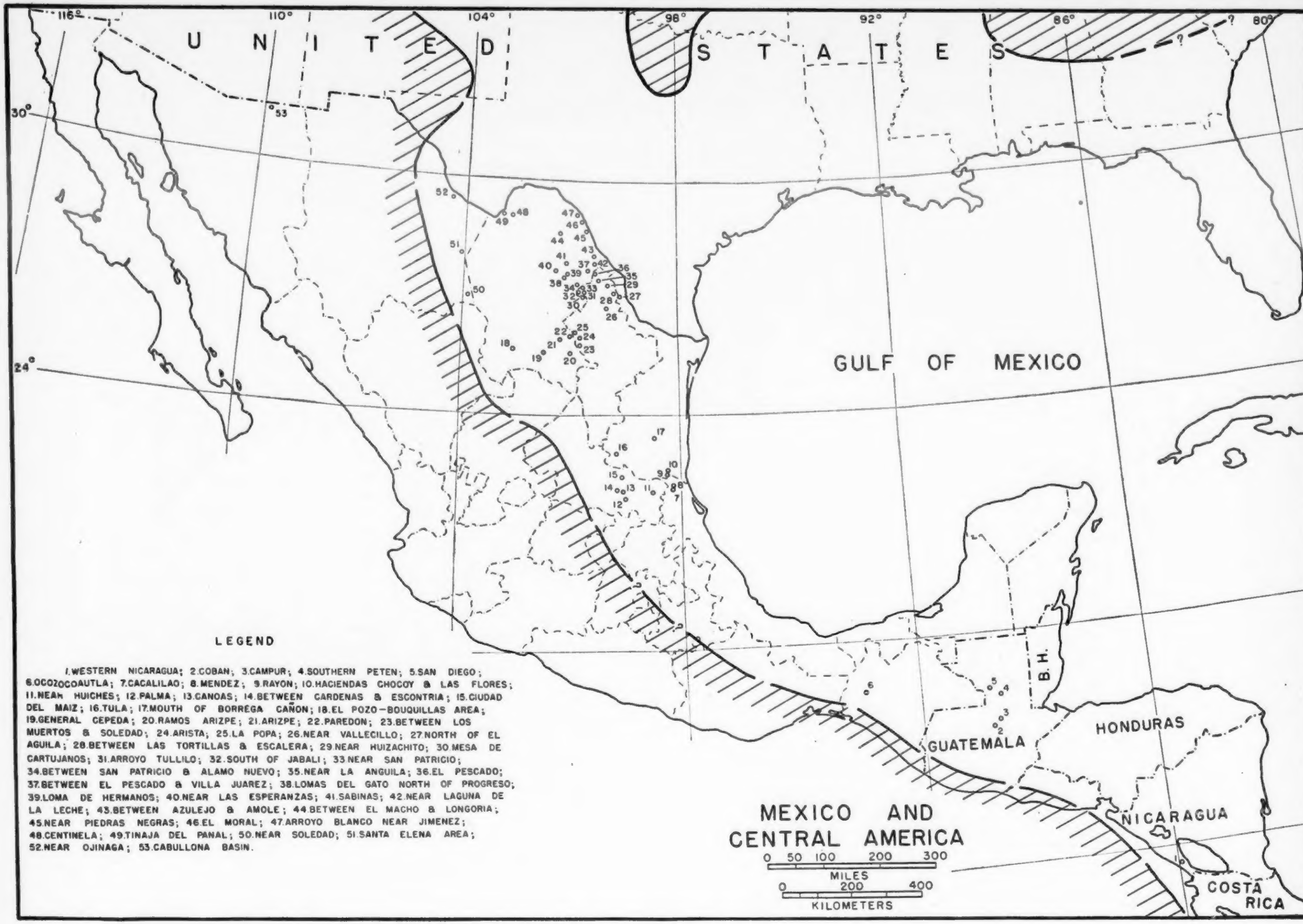


FIG. 6.—Campanian-Maestrichtian fossil localities in Central America and Mexico.

conglomerate in southwestern Coahuila. Landmasses in western Mexico were rising rapidly, as shown by the deposition of large quantities of sand and its distribution as far east as western Nuevo León and eastern San Luis Potosí. In these areas the Maestrichtian beds are much sandier than the Campanian beds, which suggests either that the sea was being crowded eastward or that the landmasses were rising at an accelerated rate. The greatest amount of sand was deposited in a trough extending eastward across southern Coahuila into central Nuevo León. This trough had been subsiding rapidly during the Coniacian and Santonian, when it received about 5,000 feet of the Parras shale, but it actually had its inception earlier, as shown by the presence near Parras, Coahuila, of over 2,000 feet of shale and limestone of upper Cenomanian-Turonian age. During the Campanian and Maestrichtian it sank at an accelerated rate and received about 20,000 feet of coarse, clastic sediment. These sediments apparently constitute the marine part of a delta built by a river draining the area of Durango and perhaps adjoining states. At the end of the Maestrichtian the sea withdrew completely from the interior of Mexico and probably beyond the present land area.

The most widespread facies of Campanian-Maestrichtian age in northern Mexico consists of sandstone, conglomerate, and some shale. In the Cabullona area of northeastern Sonora it is about 8,000 feet thick and is probably entirely continental, as will be discussed later under the description of the section in the Cabullona area. In the Ojinaga area of northeastern Chihuahua the Campanian is represented by very sandy marine shale, many beds of limestone, and some coal, which are overlain by sandstone and conglomerate possibly Maestrichtian in age. In the Santa Elena area of eastern Chihuahua occurs sandstone of Campanian or Maestrichtian age. In southeastern Chihuahua the Soledad beds consist basally of red, green, and gray marl, and higher of sandstone, conglomerate, and shale. The conglomerate contains silicified wood and plant remains. In the Parras basin of southern Coahuila between Parras and El Pozo the Difunta formation, Campanian in age, consists of sandstone, shale, and some fine limestone conglomerate and is at least 12,000 feet thick. Perhaps part of the thick sequence of sandstone and shale south of Opal in northern Zacatecas is latest Cretaceous in age. In the Saltillo area of southeastern Coahuila and west-central Nuevo León the beds of Campanian age are comparable lithologically and in thickness with beds of that age near Parras and are overlain by at least several thousand feet of similar beds of Maestrichtian age that are generally referred to the Escondido formation. From Saltillo northward the Difunta formation grades into about 1,000 feet of Méndez shale in east-central Coahuila, and the overlying sandstone, conglomerate, and shale of Maestrichtian age thin to 1,600 feet or less in east-central Coahuila. Beds containing brackish-water fossils have been identified near Lampazos and El Pescado in eastern Coahuila and are probably Maestrichtian in age. They were called the Tulillo beds by Böse and Cavins,[20]

[20] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern México," *Univ. Texas Bull. 2748* (1927), pp. 37-40.

FIG. 6.—Campanian-Maestrichtian fossil localities in Central America and Mexico.

who claimed that the beds extend from El Pescado south-southwest to Saltillo. Between Eagle Pass and Las Esperanzas, Coahuila, the Escondido formation is only about 750 feet thick and is underlain by the coal-bearing Olmos formation, lower Maestrichtian in age. All the sandy beds of late Upper Cretaceous age are considered to grade into the Méndez shale of eastern Nuevo León.

A shale facies of Campanian and Maestrichtian age is widespread in Nuevo León, Tamaulipas, and northern Veracruz. It is represented mainly by the Méndez shale, whose lower part extends as far west as Canoas in eastern San Luis Potosí and as far west as Monclova in east-central Coahuila, but whose upper part is replaced in those areas by a sandy facies. Throughout most of its extent the Méndez shale is about 700 to 1,000 feet thick, but along the northern side of the Sierra de San Carlos of Tamaulipas is about 2,850 feet thick. This greater thickness, as well as the eastward-trending structure of the Sierra de San Carlos, may be related in origin to the geosynclinal trough that extended eastward across southern Coahuila and west-central Nuevo León during Upper Cretaceous time. In southern Tamaulipas and northern Veracruz the Méndez shale is overlain disconformably by the Tamesí formation, which consists mainly of shale, 200 to 1,300 feet thick, and is now considered early Tertiary in age. In southern Nicaragua west of Lake Nicaragua are exposed 6,800 feet of shale and sandstone reported to be Taylor and Navarro in age.

Rudistid-bearing limestone interbedded with some marl, shale, and sandstone containing various mollusks, corals, echinoids, and many microfossils has been identified in the Cárdenas area of eastern San Luis Potosí, in west-central San Luis Potosí, in central and northern Guatemala, and in British Honduras. Near Cárdenas the rudistid limestone is included in the Cárdenas formation, which is reported to be between 5,000 and 10,000 feet thick, and which contains fossils of Maestrichtian age. It is not known how much of the 1,300 to 3,300 feet of the Upper Cretaceous sequence in central and northern Chiapas pertains to the Campanian and Maestrichtian.

The fossils characteristic of the Campanian and Maestrichtian beds of México and Central America are generally the same as those that characterize the Taylor and Navarro formations of Texas. In the sandy and calcareous beds the Campanian is indicated roughly by *Exogyra ponderosa* Roemer and the Maestrichtian by *Exogyra costata* Say and *Sphenodiscus*. The sandy beds also contain many species of *Inoceramus* which indicate a relationship with the faunas of the Western Interior of the United States. The Méndez shale contains many Foraminifera identical with species in the Taylor and Navarro formations. The Foraminifera in the Tamesí formation are reported to be different from those in the Navarro formation and to be identical with those in the basal Midway of Florida and Mississippi. The rudistid-bearing limestone of the Cárdenas formation of eastern San Luis Potosí, of certain calcareous beds in the Méndez shale, Tamaulipas, and of the San Cristóbal formation of Chiapas, northern Guatemala, and British Honduras, contains many species of rudistids, of which some may be useful zone fossils, but their vertical ranges have not been determined.

CENTRAL AMERICA

SOUTHERN NICARAGUA

Upper Cretaceous beds are exposed in the area between Lake Nicaragua and the Pacific Ocean, according to C. H. Wegemann,[21] who says,

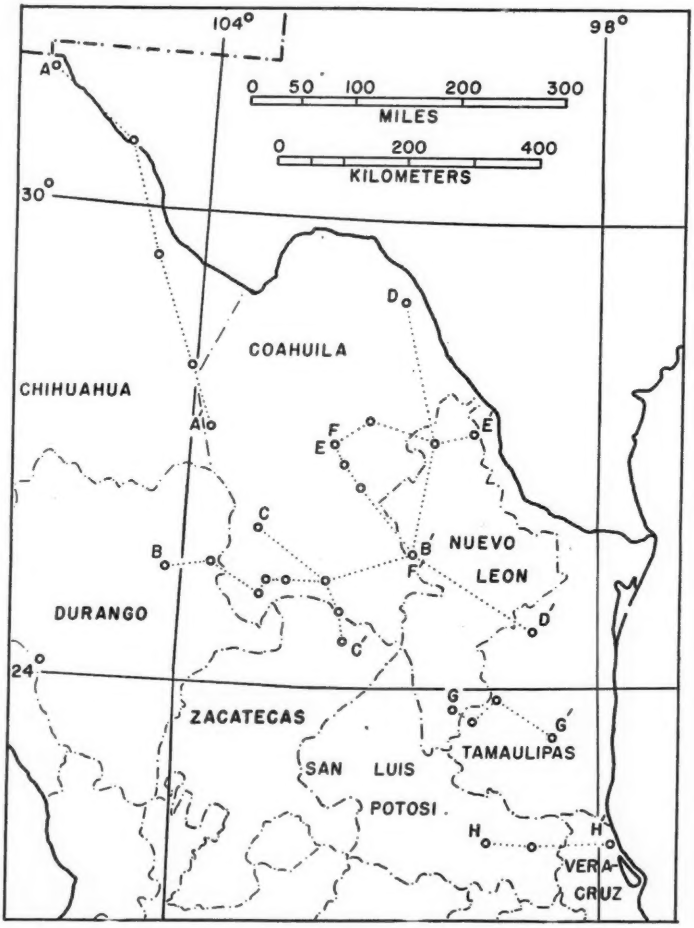


Fig. 7.—Index map of columnar sections in Mexico.

Upper Cretaceous shales and sandstones 5,000 feet in thickness are for the first time recognized in Nicaragua and can be correlated by foraminifera with the Mendéz of the Tampico region in Mexico and the Taylor and Navarro of Texas. Such correlation infers inter-

[21] C. H. Wegemann, "Geology of Southern Nicaragua," *Bull. Geol. Soc. America*, Vol. 42 (1931), p. 194.

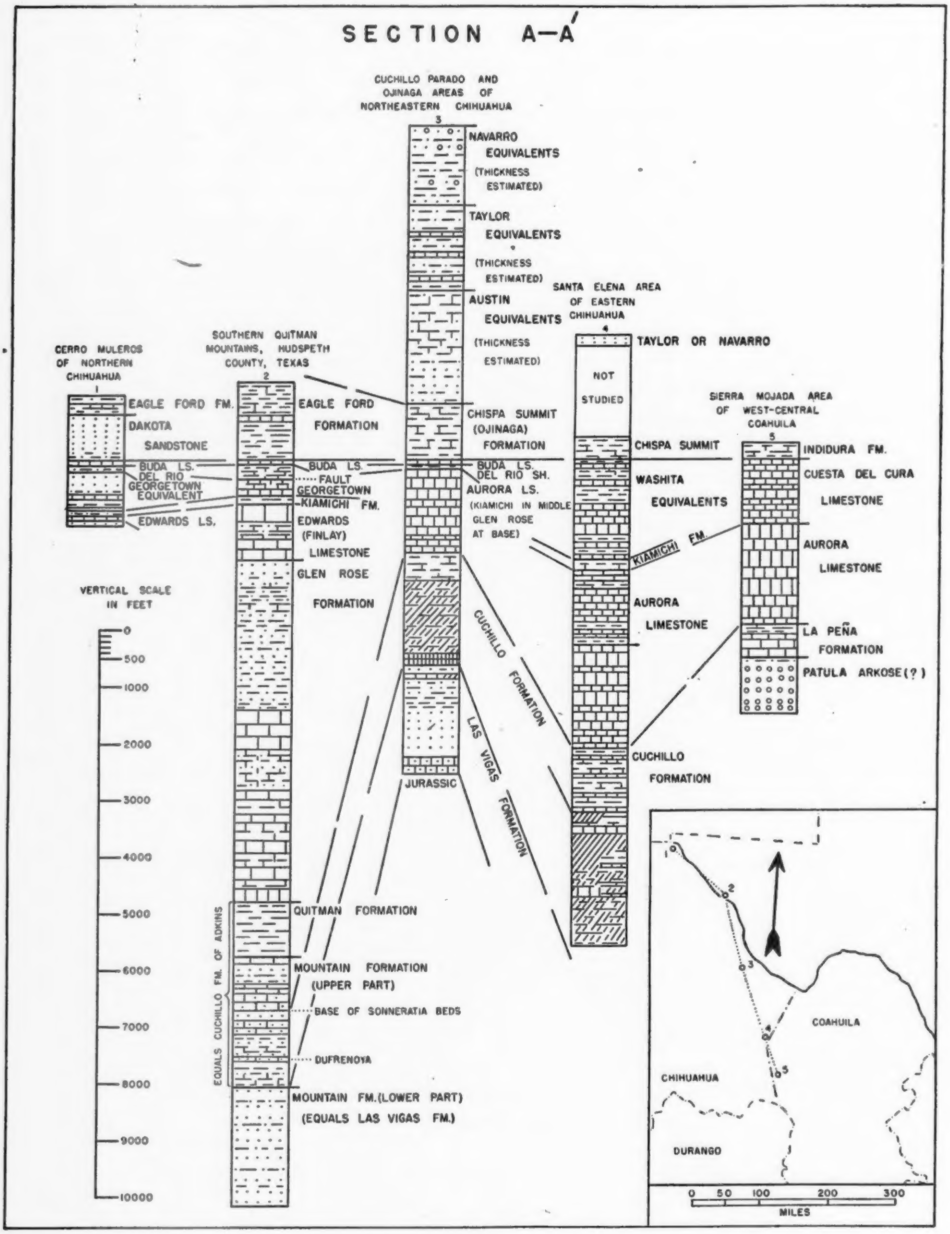


FIG. 8.—Columnar section *AA'* in eastern Chihuahua, western Texas, and western Coahuila.

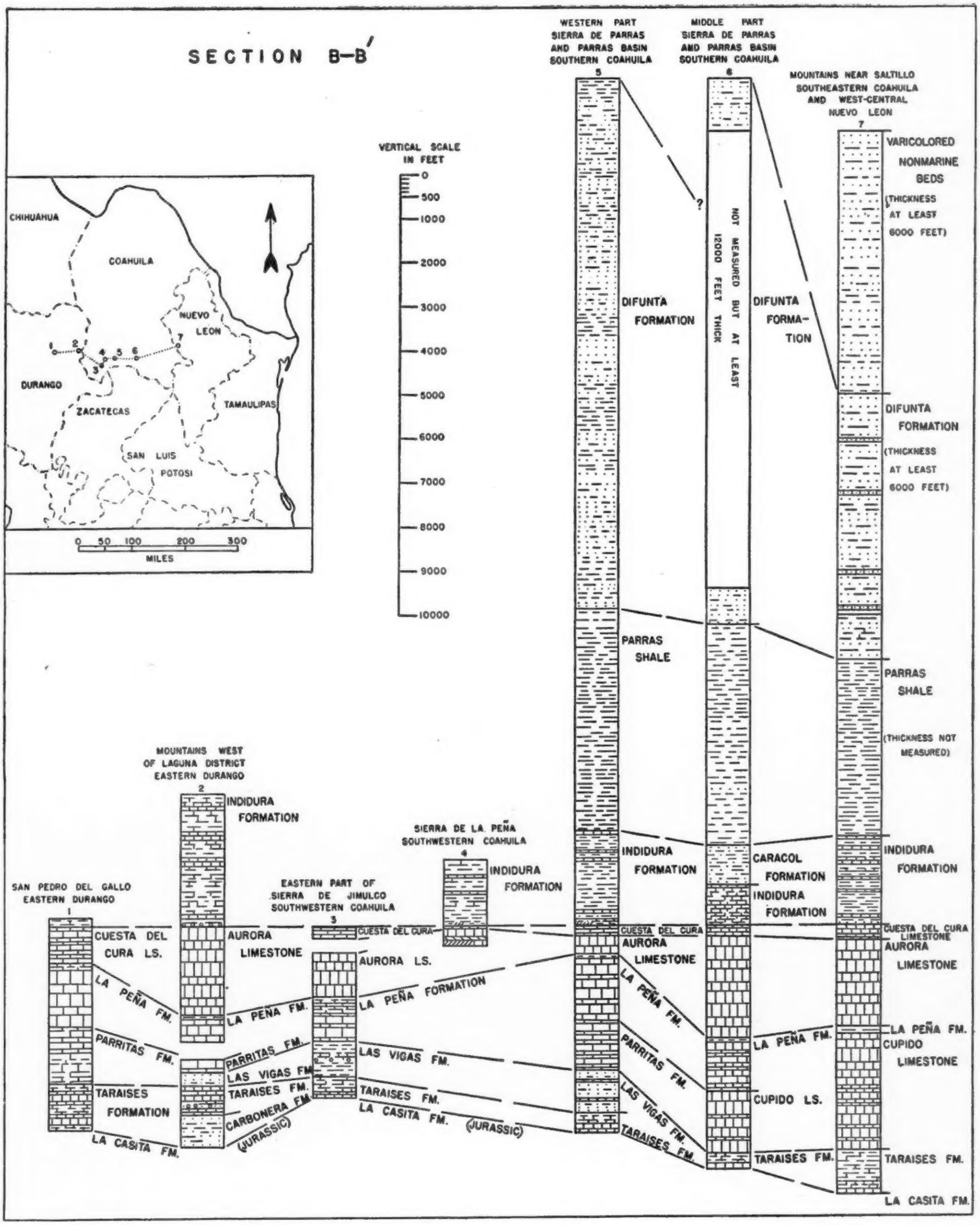


FIG. 9.—Columnar section *BB′* in eastern Durango, southern Coahuila, and west-central Nuevo León.

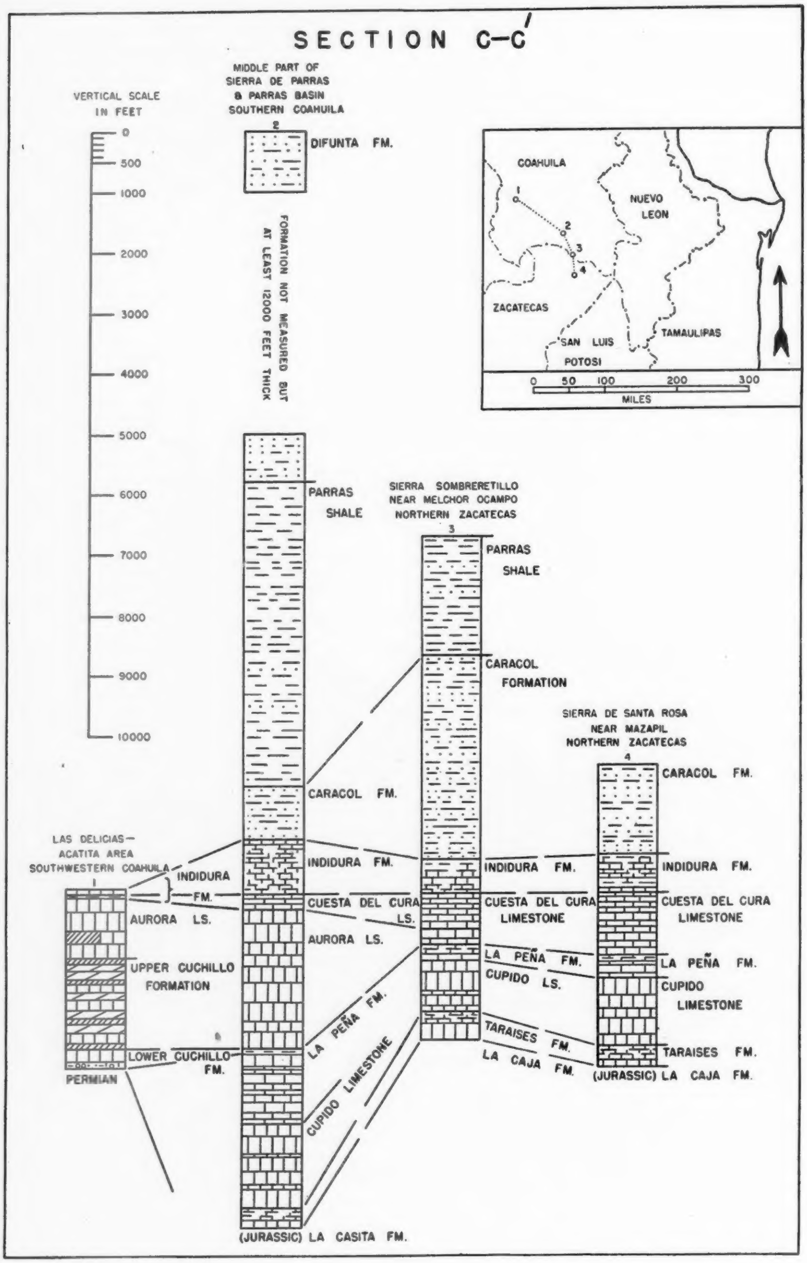


Fig. 10.—Columnar section *CC'* in southern Coahuila and northern Zacatecas.

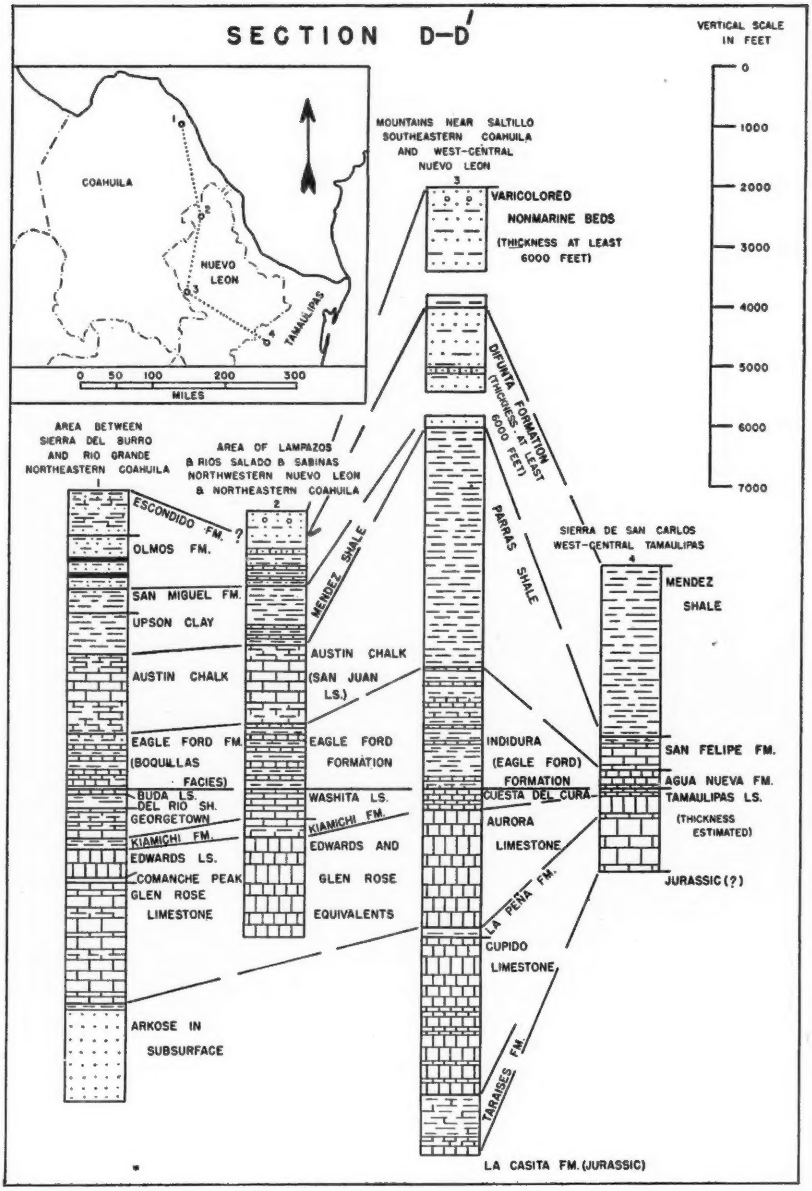


FIG. 11.—Columnar section *DD'* in eastern Coahuila, northern Nuevo León, and western Tamaulipas.

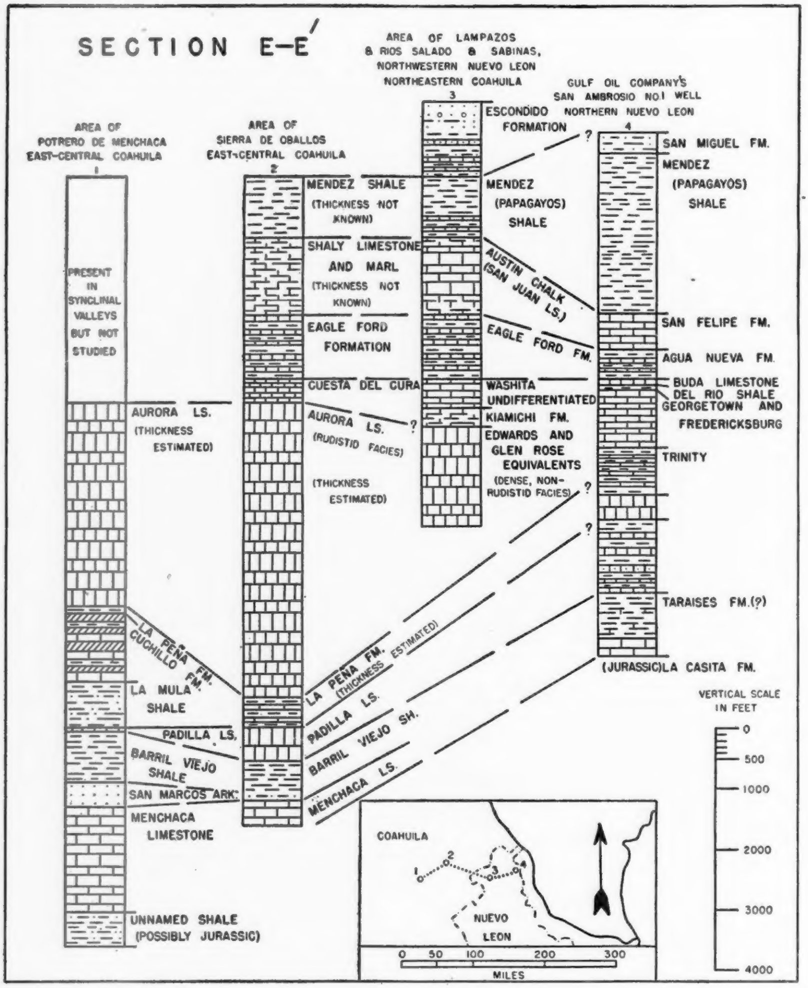


FIG. 12.—Columnar section *EE'* in eastern Coahuila and northern Nuevo León.

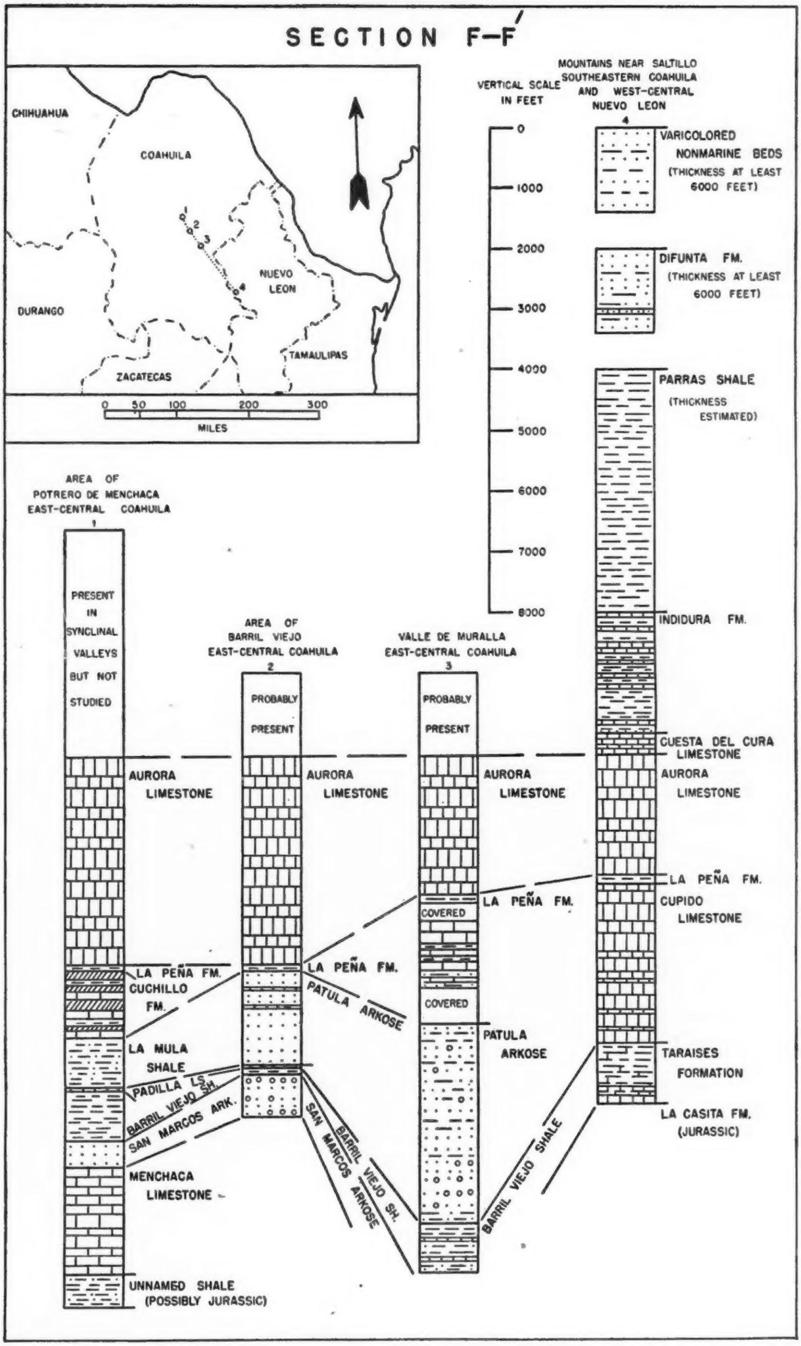


FIG. 13.—Columnar section *FF'* in eastern Coahuila and west-central Nuevo León.

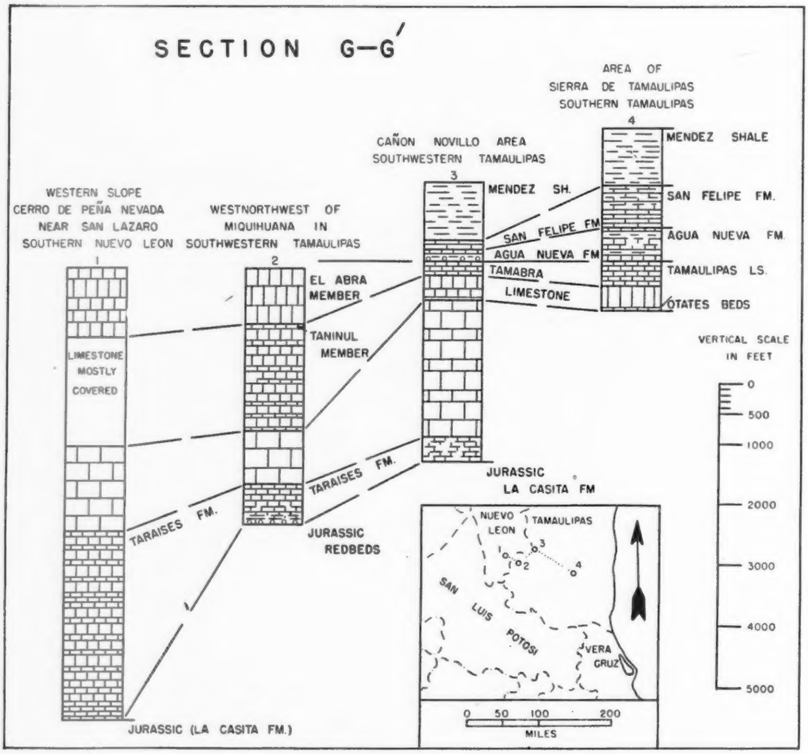


FIG. 14.—Columnar section *GG'* in southern Nuevo León and Tamaulipas.

oceanic connection between the Atlantic and Pacific in Upper Cretaceous time. . . . There was continuous sedimentation from Cretaceous to Oligocene and the different periods can be distinguished only by their foraminifera. . . .

Wegemann later added in a letter to Schuchert[22] that the Upper Cretaceous contains much volcanic material and has an exposed thickness of 6,800 feet.

EL SALVADOR, HONDURAS, AND SOUTHERN GUATEMALA

The Metapán beds of southern Guatemala, northwestern Salvador, and western and central Honduras consist of several hundred meters of conglomerate, sandstone, marl, shale, and some interbedded limestone similar to the Todos Santos beds of Jurassic-Neocomian age in northern Guatemala and Chiapas,

[22] Charles Schuchert, *Historical Geology of the Antillean-Caribbean Region* (1935), pp. 607, 608.

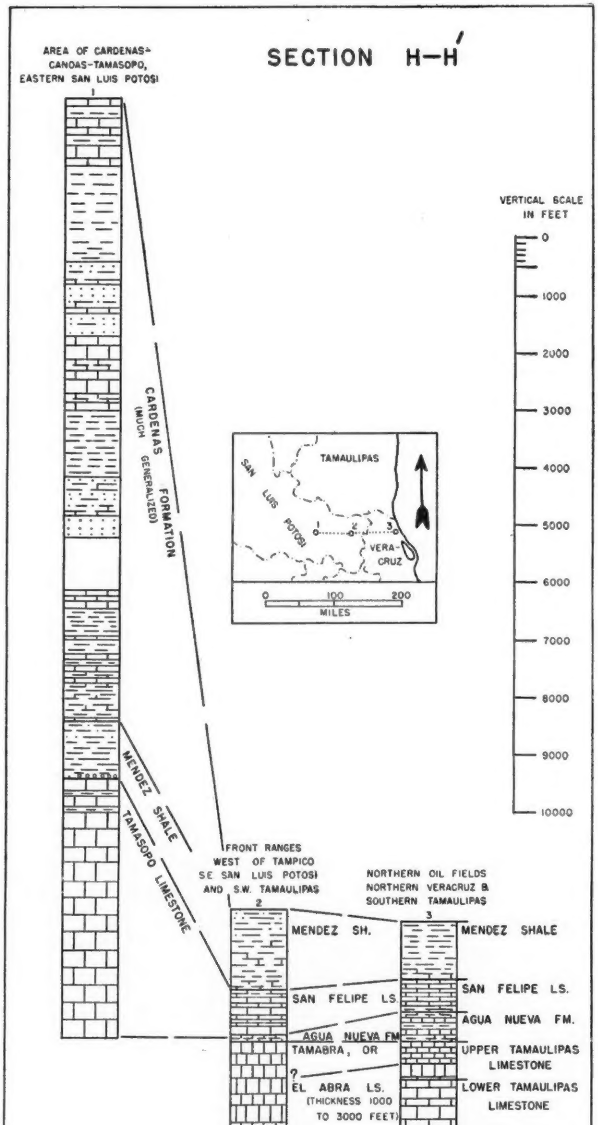


FIG. 15.—Columnar section *HH'* in eastern San Luis Potosí and northern Veracruz.

and to the Tegucigalpa beds of southern Honduras.[23] Sapper considered the Metapán beds equivalent to the Todos Santos beds and probably equivalent to the upper part of the Tegucigalpa beds. Mullerried[24] partially confirmed this by finding plants of Lower and Middle Jurassic age in the Metapán beds, but he did not find fossils in the Tegucigalpa beds[25] or any Neocomian fossils south of Chiapas.

The Metapán beds are overlain concordantly by a considerable thickness of gray, thin- to thick-bedded limestone, marly limestone, marl, conglomeratic limestone, and locally by beds containing chert concretions. From these beds at many places in Honduras and near Metapán in El Salvador were obtained middle Albian fossils,[26] including *Toucasia texana* Roemer and *T. patagiata* (White). Near Guatemala City was found an *Orbitolina* similar to *O. texana* (Roemer),[27] from the Glen Rose formation of Texas, which represents lower Albian and part of the middle Albian. Fossils from limestone in central Honduras were determined by P. de Loriol and J. Böhm[28] as probably upper Neocomian, but, if their identifications are correct, the age of the fossils must be upper Albian (Washita). Weaver[29] presumably includes these late Lower Cretaceous limestones in the Metapán beds, but his usage does not correspond with that of Sapper or other writers on Central American geology.

No positive fossil evidence has been presented for the existence of Upper Cretaceous beds in Honduras and El Salvador, or in southern Guatemala south of a belt of granitic and metamorphic rocks[30] that trends eastward just north of Guatemala City. The Esquias formation, proposed by Weaver[31] for about 1,000 feet of hard, gray, thick-bedded limestone with some interbedded brown sandstone, shale, and conglomerate outcropping near Esquias in north-central Honduras, has been considered Upper Cretaceous solely on the basis of stratigraphic position, as the only listed fossils, *Lima* and *Inoceramus*, are not restricted to the Cretaceous.

[23] Karl Sapper, "Mittelamerica," *Handbuch der Regionalen Geologie*, Band 8, Abt. 4a, Heft 29 (1937), pp. 26, 27, 109.
F. K. G. Mullerried, "Investigaciones y exploraciones geográfico-geológicas en la porción nor-oeste de la América Central," *Instituto Panamericano de Geografía e Historia Pub. 38* (1939a), pp. 47b, c.

[24] F. K. G. Mullerried, *op. cit.*, pp. 47b, c.
———, "The Mesozoic of Mexico and Northwestern Central America," *Proc. Eighth Amer. Scientific Congress*, Vol. 4 (1942a), p. 129.
———, "Contributions to the Geology of Northwestern Central America," *op. cit.* (1942b), pp. 474, 475.

[25] F. K. G. Mullerried, *op. cit.* (1939a), p. 30.

[26] *Ibid.*, pp. 28, 45–47.

[27] T. W. Vaughan, "The Foraminiferal Genus *Orbitolina* in Guatemala and Venezuela," *Proc. Nat. Acad. Sci.*, Vol. 18, No. 10 (1932), p. 610.

[28] Karl Sapper, *op. cit.* (1937), p. 27.

[29] Charles E. Weaver, "A General Summary of the Mesozoic of South America and Central America," *Proc. Eighth Amer. Sci. Congress*, Vol. 4 (1942), p. 180.

[30] F. K. G. Mullerried, *op. cit.* (1942b), pp. 470, 478.

[31] Charles Schuchert, *op. cit.* (1935), pp. 354, 355. Charles E. Weaver, *op. cit.* (1942), pp. 179, 180.

NORTHERN GUATEMALA AND BRITISH HONDURAS

The Cretaceous formations of Guatemala are very similar to those of Chiapas and probably should be recognized by the same names. Neocomian fossils have not been found in the upper part of the Todos Santos beds as in Chiapas, but the lower part of the beds in Guatemala has furnished plants of Lower and Middle Jurassic age.[32] The late Lower Cretaceous is represented by the lower part of the Cobán limestone of central Guatemala or by equivalent beds that have furnished fossils of lower and middle Albian age. The evidence summarized recently by Mullerried[33] consists mainly of *Orbitolina texana* Roemer for the lower Albian and of *Toucasia texana* (Roemer) for the middle Albian (Fredericksburg). The thickness of the late Lower Cretaceous limestones is probably more than several hundred meters. The Upper Cretaceous beds consist mainly of limestone, dolomite, and limestone conglomerate,[34] similar to the Upper Cretaceous of Chiapas[35] and have furnished many rudistids indicating ages from upper Turonian to Maestrichtian.[36] Evidence for the late Upper Cretaceous age of some beds in southern Petén, Guatemala, is furnished by the presence of *Pseudorbitoides israelskii* Vaughan and Cole,[37] whose type specimens come from beds of lower Taylor age in Louisiana. A slightly older age is suggested by an association of land plants and *Inoceramus* from the Verapaz district of north-central Guatemala.[38] The plants are said to indicate a Santonian or Campanian age. One of the species of *Inoceramus* "appears to be closely related to if not identical with *Inoceramus deformis* Meek, a species which is common in the Austin chalk of Texas and in the Niobrara limestone of the Western Interior of the United States."

[32] F. K. G. Mullerried, "Investigaciones y exploraciones geográfico-geológicas en la porción nor-oeste de la América Central," *Instituto Panamericano de Geografía e Historia Pub. 38* (1939a), pp. 42, 47c.

———, "Contributions to the Geology of Northwestern Central America," *Proc. Eighth Amer. Scientific Congress*, Vol. 4 (1942b), pp. 470, 474, 475.

[33] F. K. G. Mullerried, *op. cit.* (1939a), pp. 28, 41, 45–47.

———, "The Mesozoic of Mexico and Northwestern Central America," *Proc. Eighth Amer. Scientific Congress*, Vol. 4 (1942a), pp. 134, 136.

———, *op. cit.* (1942b), p. 476.

[34] R. E. Dickerson and N. E. Weisbord, "Cretaceous Limestone in British Honduras," *Jour. Geol.*, Vol. 39 (1931), pp. 483–86.

[35] F. K. G. Mullerried, "Estratigrafía preterciaria preliminar del Estado de Chiapas," *Bol. Soc. Geol. Mexicana*, T. 9 (1936), pp. 37–39.

[36] F. K. G. Mullerried, *op. cit.* (1942b), pp. 476, 477.

H. J. MacGillavry, "Some Rudists from the Alta Verapaz, Guatemala," *Proc. K. Akad. Wetensch. Amsterdam*, Vol. 37, No. 4 (1934), pp. 232–38.

[37] T. W. Vaughan and W. Storrs Cole, "Cretaceous Orbitoidal Foraminifera from the Gulf States and Central America," *Proc. Nat. Acad. Sci.*, Vol. 18, No. 10 (1932), Pl. 2, pp. 614–16.

[38] L. W. Stephenson and E. W. Berry, "Marine Shells in Association with Land Plants in the Upper Cretaceous of Guatemala," *Jour. Paleon.*, Vol. 3 (1929), 2 pls., pp. 157–62.

MEXICO

CHIAPAS

A fairly complete Cretaceous sequence in Chiapas has been demonstrated by Mullerried[39] on the basis of many fossil collections obtained during eight field seasons. He was one of the first to recognize the Neocomian age of the upper part of the Todos Santos beds[40] and the Upper Cretaceous age of a thick section which had been considered of Eocene age.[41] He estimated the total thickness of the Cretaceous as about 1,500 meters (4,920 feet).

The beds of Neocomian age in Chiapas, according to Mullerried,[42] consist of sandstone, shale, marly limestone, and red sandstone and shale about 150 meters (492 feet) thick. Their basal part contains a large fauna of pelecypods, gastropods, brachiopods, and Foraminifera, and about 30 meters higher a bed of greenish sandstone contains plant remains. They appear to be identical lithologically and in stratigraphic position with the Tuxtla formation of central Chiapas defined by Ver Wiebe.[43] The Tuxtla formation consists mainly of argillaceous shale, sandy shale, and red shale but includes some thick beds of limestone and sandstone, ranges in thickness from 975 to 1,300 feet, and lies directly beneath limestone of late Lower Cretaceous age.

The Neocomian beds are overlain, according to Mullerried,[44] by about 400 meters (1,312 feet) of thick-bedded limestone and conglomeratic limestone that contain miliolids and poorly preserved gastropods, and are probably Albian to Cenomanian in age. They apparently correspond with the lower part of the Cobán limestone (equals Ixcoy limestone, Comitán limestone, White limestone) of Guatemala,[45] which Mulleried[46] considers is at least in part of Turonian age.

The Upper Cretaceous beds[47] consist of sandstone, marl, marly and sandy limestone, and dolomite, range in thickness from 400 to 1,000 meters (1,312 to

[39] F. K. G. Mullerried, *op. cit.* (1936), pp. 36–39.

[40] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 97, 98.
Franz Termer, "Geologie von Nordwest-Guatemala," *Zeitschr. Gesell. Erdkunde Berlin*, Nos. 7, 8 (1932), p. 246.

[41] Karl Sapper, *op. cit.* (1937), pp. 30, 97.
J. J. Galloway and Margaret Morrey, "Late Cretaceous Foraminifera from Tabasco, México," *Jour. Paleon.*, Vol. 5 (1931), pp. 329–54.

[42] F. K. G. Mullerried, *op. cit.* (1936), p. 36.

[43] W. A. Ver Wiebe, "Geology of Southern Mexico Oil Fields," *Pan-Amer. Geol.*, Vol. 44, No. 2 (1925), pp. 129, 131.
Emil Böse, "Reseña acerca de la geología de Chiapas y Tabasco," *Bol. Inst. Geol. México*, Núm. 20 (1905), pp. 25, 26.
Charles Schuchert, *op. cit.* (1935), pp. 328, 329.

[44] F. K. G. Mullerried, *op. cit.* (1936), p. 37.

[45] Karl Sapper, *op. cit.* (1937), pp. 28, 29, 47, 95, 96, 101, Pls. 5a, 5b.

[46] F. K. G. Mullerried, *op. cit.* (1939a), pp. 37, 38.

[47] Karl Sapper, *op. cit.* (1937), Pls. 5a, 5b, p. 30.
F. K. G. Mullerried, *op. cit.* (1936), pp. 38, 39; (1942a), p. 140.

3,280 feet), and are widely distributed in central and northern Chiapas. They are included in the San Cristóbal limestone of Ver Wiebe,[48] which, as defined, includes the Cretaceous above the Tuxtla formation. Their age has been discussed by Mullerried[49] as follows (translation).

Of the Upper Cretaceous, the lower Turonian can not be demonstrated because of lack of characteristic fossils. The upper Turonian is characterized by *Distefanella lombricalis* (D'Orbigny) Douvillé, *Sauvagesia* cf. *S. da Rio Catullo*, and *Radiolites* aff. *R. lusitanicus* Bayle, species known from the upper Turonian of the Old World, and by *Apricardia* sp., which is found in the beds with *Hippurites resectus* var. *mexicana* of Apaxco, Mex., from the upper Turonian.

Also in this series is found *Sauvagesia degolyeri* Stanton, whose types came from the lower part of the San Felipe formation of the Huasteca region, and the famous *Barrettia*, known in Jamaica, Cuba, and Guatemala, but until now recognized as pertaining to the upper Senonian. In reality *Barrettia* pertains to the upper Turonian, as I have shown in a recent article. *Barrettia* is accompanied by *Plagioptychus toucasi* Mathéron and other pachyodonts of the Turonian of Europe.

At the limit of this stage and the following, the Coniacian, are two levels of ammonites: the lower level contains *Lytoceras* (*Gaudryceras*) sp. ind., *Pachydiscus peramplus* var. *beyrensis* Choffat, *Acanthoceras* sp. ind., and pertains still to the Turonian; the upper level contains *Hauericeras* sp. ind., a genus that characterizes the Senonian. Between these two levels pass, then, the limit of the Turonian and the Senonian.

The lower stage of the latter, the Coniacian, contains *Chiapasella radiolitiformis* (Trechmann) Mullerried and *Pseudobarrettia*, which are accompanied by *Biradiolites canaliculatus* D'Orbigny, characteristic of the Coniacian of France, according to Toucas; and of *Durania* cf. *D. austinensis*, whose type comes from the Coniacian of Texas. The Coniacian and the lower Santonian of Chiapas are characterized by *Radiolites* cf. *R. subradiosus* Toucas, and the lower Santonian by *Vaccinites giganteus* d'Hombres-Firmas var. *major* Toucas and *Radiolites* cf. *R. galloprovincialis* Mathéron.

Finally the presence of the Campanian is proved by *Praeradiolites* aff. *P. subcoquandi* Toucas, whose type comes from this stage. A little higher in this zone in Chiapas are found beds very similar to those at Cardenas, S.L.P., because they have *Coralliochama*, *Biradiolites aguilerae* Böse, *Actaeonella occidentalis* Böse, and *Biradiolites cardenasensis* Böse. The latter species is very similar to *Biradiolites orbignyi* Toucas from the Campanian of France.

For this reason and because there are pachyodonts higher in the series in question, I am inclined to believe that the beds with *Coralliochama* (Division of Cárdenas) pertain to the Campanian. They do not pertain to the lower Senonian as indicated by Böse, because they are superimposed on the Santonian in Chiapas. To the Campanian and Maestrichtian pertain then the beds with *Coralliochama*, and the overlying beds that contain pachyodonts; the beds still higher but without pachyodonts are very probably Tertiary.

MacGillavry[50] considers that Mullerried's age determinations are erroneous and that the apparent occurrence of such genera as *Barrettia* and *Plagioptychus* below upper Turonian ammonites must be a result of some structural complica-

[48] W. A. Ver Wiebe, *op. cit.* (1925), pp. 129, 132.

[49] F. K. G. Mullerried, *op. cit.* (1936), pp. 38, 39.

[50] H. J. MacGillavry, "Geology of the Province of Camagüey, Cuba, with Revisional Studies in Rudist Paleontology," *Geog. Geol. Mededeel. Phys.-Geol. Reeks*, No. 14 (1937), pp. 23–28.

tion that was overlooked by Mullerried. The exact dating of the various rudistid species and genera in Mexico will have to be made on the basis of other associated fossils.

ISTHMUS OF TEHUANTEPEC

Neocomian limestone cropping out near Tonalapa in the Chinameca area and on Cerro Pelón near Río Las Playas has been called the Chinameca limestone by Gibson.[51] Its lower part consists of gray, yellow, or brown, platy limestone, of which some beds are extremely thin. Its upper part consists of grayish brown, shaly limestone and whitish, calcareous shales. Thicknesses of individual units have not been recorded, but the entire late Upper Jurassic-Neocomian sequence has a thickness of 250 to 300 meters (820 to 984 feet).[52] The lower Neocomian age of some of the beds is shown by the presence of *Olcostephanus* and *Neocomites*. The upper Neocomian to Aptian age of the highest beds is indicated by the presence of *Puzosia* group of *P. liptoviensis* Zeuschner (equals *Pseudohaploceras*).

Beds of late Lower Cretaceous and early Upper Cretaceous age cropping out in the extreme southeastern part of Veracruz and in the adjoining northeastern part of Oaxaca[53] consist mainly of gray, thick-bedded limestone and dolomite, are characterized by many rudistids,[54] and attain a thickness of about 3,000 feet. They are commonly called the Sierra Madre limestone. Beds of late Upper Cretaceous age are probably present, judging by Mullerried's[55] studies in Chiapas, but have not been identified by fossils.

WEST-CENTRAL OAXACA

Rocks of lower Neocomian age have been identified at several places in Oaxaca. In the Cerro de la Virgin south of Tlaxiaco the Berriasian is probably represented by forms of *Subthurmannia* occurring in bituminous, marly shale at the top of an Upper Jurassic sequence.[56] At Parián ammonites referable to *Olcostephanus* and *Kilianella* were obtained from grayish green, marly limestone.[57]

[51] Juan B. Gibson, "Estratigrafía y tectónica de la zona costera del Golfo entre 19°34′ latitud norte y el Rio Coatzacoalcos, Veracruz," *Bol. Soc. Geol. Mexicana*, T. 9, Núm. 5 (1936), table opposite p. 288.

[52] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 97, 98.

[53] W. A. Ver Wiebe, *op. cit.* (1925), pp. 124, 125, 132.
C. L. Baker, "Geological Cross Section of the Isthmus of Tehuantepec," *Pan-Amer. Geologist*, Vol. 53 (1930), pp. 170, 171.
Juan B. Gibson, *op. cit.* (1936), p. 276.

[54] Carlos Burckhardt, *op. cit.* (1930), p. 193.

[55] F. K. G. Mullerried, "Estratigrafía preterciaria preliminar del Estado de Chiapas," *Bol. Sòc. Geol. Mexicana*, T. 9 (1936), pp. 37–39.

[56] Carlos Burckhardt, *op. cit.* (1930), p. 99.
Johannes Felix, "Versteinerungen aus der mexicanischen Jura- and Kreide Formation," *Paleontographica*, Vol. 37 (1891), p. 141.

[57] Tomás Barrera, "Discusión sobre las ideas del Dr. Palmer sobre la geología de Oaxaca y sobre las posibilidades de la acumulación del petróleo en la costa," *Revista Industrial*, T. 1, Núm. 1 (1933), 61–67.
Carlos Burckhardt and F. K. G. Mullerried, "Neue Funde in Jura und Kreide Ost- und Sud-Mexicos," *Eclogae Geol. Helvetiae*, Vol. 29, No. 2 (1936), p. 318.

From Monte Alban south-southwest of the city of Oaxaca a specimen of *Olcostephanus* was obtained from gray to yellow, marly shale. Barremian and Aptian beds have not been identified by fossils, although the lower Neocomian shale near the City of Oaxaca is overlain by compact, gray limestone similar to limestone of upper Neocomian age near Tehuacán in southeastern Puebla.[58] The limestone near Oaxaca, according to Burckhardt[59] is overlain with angular unconformity by a limestone breccia that basally contains sandstone and fragments of gneiss and quartzite, and overlaps onto gneiss on Monte Alban. The breccia is overlain transitionally by gray, marly shale[60] that has furnished ammonites identified by Böse[61] as *Hamites* aff. *H. attenuatus* Sowerby and *Acanthoceras* cf. *A. mantelli* Sowerby (equals *Mantelliceras*) and are probably upper Albian and lower Cenomanian in age. The limestone breccia has been found at several other places in the state of Oaxaca.[62] Near Tomellin it rests on gneiss and is overlain by gray, thick-bedded limestone containing chert nodules and rudistids. Near Zimatlán it rests on gneiss. On Cerro de Tamasulapa south of Miahuatlán gray limestone containing chert nodules and rudistids rests on gneiss. Near San Pedro el Alto a series of beds consisting of limestone breccia, gray limestone with chert, marl, and a basal greensand rests on gneiss. Near Tezoatlán limestones of late Lower Cretaceous age overlap across beds of Upper and Middle Jurassic age. Outside of Oaxaca the unconformable relationship of late Lower Cretaceous limestone on older beds had been observed at many places in the States of Veracruz, Puebla, Guerrero, and Michoacán. The unconformity in the Tehuacán area of southeastern Puebla is dated by Burckhardt as younger than upper Aptian and older than upper Albian, but it may not represent all of lower and middle Albian time.

Rudistid-bearing limestone near Ejutla, Oaxaca, has been assigned to the Turonian by Böse,[63] Palmer,[64] and Mullerried[65] on the presence of "*Biradiolites*" *lombricalis* D'Orbigny and *Apricardia chavesi* Palmer.

[58] Carlos Burckhardt, *op. cit.* (1930), pp. 202, 203.
F. K. G. Mullerried, "Estudios paleontológicos y estratigráficos en la región de Tehuacán, Puebla," *Anales Inst. Biología México*, T. 4, Núm. 2 (1933), pp. 80, 82.

[59] Carlos Burckhardt, *op. cit.* (1930), pp. 162, 201–03.
Johannes Felix and H. Link, "Beiträge zur Geologie und Palaeontologie der Republik Mexico," Theil 2, Heft 1, "Uebersicht über die geologischen Verhältniss des mexicanischen Staates Oaxaca," *Palaeontographica*, Vol. 37 (1893), pp. 12–36.

[60] Carlos Burckhardt, *op. cit.* (1930), p. 203.

[61] Emil Böse, "Neue Beiträge zur Kenntnis der mexikanischen Kreide," *Centralbl. Min. Geol. und Palaeont.* (1910a), p. 654.

[62] Carlos Burckhardt, *op. cit.* (1930), pp. 202–05.

[63] Emil Böse, *op. cit.* (1910a), p. 658.

[64] R. H. Palmer, "The Rudistids of Southern Mexico," *California Acad. Sci. Occ. Paper 14* (1928), p. 42.

[65] F. K. G. Mullerried, "El *Biradiolites lombricalis* D'Orb. sp. de Ejutla, Edo. de Oaxaca," *Anales Inst. Biología México*, T. 3 (1932b), 1 fig., pp. 237–42.

COLIMA, SOUTHERN JALISCO, AND WESTERN MICHOACAN

In this area a thick sequence of limestone and marl has furnished fossils indicating ages from lower Albian to Turonian. The lower and middle Albian are apparently represented near the city of Colima and near Túxpan, Tapalpa, and Talpa, in Jalisco, by greenish yellow to gray marl alternating with thick beds of gray limestone and some dark shale. Volcanic material occurs in some of the marls. Some limestone beds contain many Orbitolinas, molds of bivalves, and the gastropod *Cassiope*. The upper Albian has been identified near Colima and Túxpan, where it consists of gray to yellow, thin-bedded limestone alternating with lenses and beds of black chert and has furnished ammonites of the genus *Mortoniceras* (*Pervinquieria*).[66] The Cenomanian has been identified at Coalcoman in Michoacán, near the city of Colima, and near Túxpan and Soyatlán de Adentro in Jalisco. Near Coalcoman occurs a sequence of limestone, marl, shale, and sandstone that is mainly gray to brown in color and has furnished a large fauna of rudistids, Nerineas and the aberrant pelecypod *Chondrodonta*.[67] Only part of the sequence may be of Cenomanian age. Near Paso del Río between the City of Colima and the Pacific Ocean the Cenomanian is represented by gray, thick-bedded limestone containing numerous rudistids.[68] Near Túxpan the Cenomanian is represented by gray, thick-bedded rudistid limestone and perhaps also by underlying greenish yellow marl. Near Soyatlán de Adentro occurs about 100 feet of limestone conglomerate containing a large rudistid fauna. One of the most frequently cited Cenomanian rudistids is *Coalcomana ramosa* (G. Boehm).

The Turonian is represented, according to Palmer,[69] by rudistid-bearing limestone near Huescalapa and Soyatlán de Adentro in Jalisco. *Apricardia chavezi* Palmer occurring at the latter locality is much like a Turonian species from Italy, according to Palmer.[70]

PUNGARABATO-HUETAMO AREA OF NORTHERN GUERRERO AND SOUTHEASTERN MICHOACÁN

In the area between Pungarabato and Huetamo[71] the Neocomian is apparently represented by olive-colored shale containing thin coal beds, by gray to

[66] Emil Böse, *op. cit.* (1910a), p. 653.
Carlos Burckhardt, *op. cit.* (1930), p. 206.

[67] G. Boehm, "Ueber Caprinidenkalke aus Mexico," *Zeitschr. Deutsche geol. Gesell.*, Vol. 50 (1898), illus., pp. 323–32.
———, "Beiträge zur Kenntnis mexicanischen Caprinidenkalke," in Felix and Lenk, "Beiträge zur Geologie und Paläontologie der Republik Mexico," Theil 2, Pt. 3 (1899), illus., pp. 143–54.
Henri Douvillé, "Sur quelques rudistes américains," *Bull. Soc. géol. France*, 3e Ser., T. 28 (1900), p. 205.

[68] R. H. Palmer, "The Rudistids of Southern Mexico," *California Acad. Sci. Occ. Paper 14* (1928), 18 pls., 8 figs., 137 pp.
Carlos Burckhardt, *op. cit.* (1930), p. 206.

[69] R. H. Palmer, *op. cit.* (1928), pp. 9, 26, 46.

[70] *Ibid.*, p. 42.

[71] Carlos Burckhardt, "Étude synthétique sur le mésozoïque mexicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 161, 162, 201.
C. E. Hall, "Notes on a Geological Section from Iguala to San Miguel Totolapa, State of Guerrero," *Soc. Cient. "Antonio Alzate" Mem. y Rev.*, T. 13 (1903), Pls. 5, 6, pp. 327–35.

black, fine-grained sandstone containing plant remains, by intercalations of limestone conglomerate, and by distinctly bedded limestone that predominates near the top. The age determination is based on the presence of *Nerinea titania* Felix, which occurs also in the upper Neocomian near San Antonio de Las Salinas in southeastern Puebla, and on the pronounced angular unconformity between these beds and the overlying, compact, thick-bedded limestone and calcareous shale probably late Lower Cretaceous in age.

ZUMPANGO DEL RÍO AREA OF EAST-CENTRAL GUERRERO

Limestones of late Lower Cretaceous age are reported[72] to crop out in alternate bands with marls and shales of Upper Cretaceous age on the north slope of the Sierra Madre del Sur between Mexcala and Zumpango del Río. According to Mullerried,[73] the Lower Cretaceous limestones are light to dark gray, dense to coarsely crystalline, thick- to medium-bedded, or in places thin-bedded, are in part interbedded with lenses of black to gray chert, and locally contain light-colored chert nodules, or limestone conglomerate. They have furnished many Foraminifera, echinoids, pelecypods, and gastropods, including *Orbitolina texana* (Roemer), *Toucasia texana* (Roemer), and *Toucasia patagiata* White. Still farther south, as in the mountains near Tierra Colorado and Santa Rosa, the Lower Cretaceous limestones rest directly on metamorphic rocks.

Upper Cretaceous rocks of considerable thickness outcropping near Tixtla, about 15 kilometers southeast of Zumpango del Río, have been described by Mullerried.[74] They consist of interbedded grayish marl, sandy marl, sandstone, limestone, and shaly limestone and contain many fossils. Mullerried indicates that the Santonian is represented by *Durania* cf. *D. aguilae* Adkins and *Hippurites* (*Vaccinites*) cf. *H. galloprovincialis* Mathéron. The Coniacian may be represented by an ammonite perhaps belonging to *Peroniceras*. Other stages of the Upper Cretaceous may be present.

Near Zumpango del Río occurs a thick sequence of gray, greenish, and brownish shale, marl, and marly limestone from which Burckhardt[75,76] obtained many ammonites, gastropods, a few Inocerami and some plant fragments representing the upper Turonian and lower Coniacian. He indicates several species of *Scaphites* for the Turonian and many species of *Peroniceras* and *Barroisiceras* for the Coniacian. However, among the species listed as occurring together, some would normally indicate a Turonian age, and others would indicate a Coniacian age, so there is a possibility that the fossils have been accidentally mixed. Near

[72] Carlos Burckhardt, *op. cit.* (1930), p. 236.

[73] F. K. G. Mullerried, "El valle de Tixtla, cuenca de desagüe subterráneo temporal, en el Estado de Guerrero," *Revista Geográfica del Instituto Pan-Americano de Geografía e Historia* (1942), pp. 34–36.

[74] *Ibid.*, pp. 36–38.

[75] Carlos Burckhardt, "Faunas jurásicas de Symon (Zacatecas) y faunas cretácicas de Zumpango del Río (Guerrero)," *Bol. Inst. Geol. México*, T. 1, Núm. 33 (1919), pp. 81–84, 93–132; T. 2 (1921), atlas, Pls. 22–32.

[76] Emil Böse, "Algunas faunas cretácicas de Zacatecas, Durango y Guerrero," *Bol. Inst. Geol. México*, Núm. 42 (1923a), Pls. 13–17, pp. 190–210.

Mezquititlán, a little north of Zumpango del Río, occurs limestone with the lower Turonian ammonites *Vascoceras* and *Hoplitoides* (?).[77]

MORELOS AND ADJOINING PARTS OF PUEBLA, GUERRERO, AND MÉXICO

Shale interbedded with sandstone and some thin-bedded limestone cropping out between Iguala and Teloloapán in northern Guerrero[78] have been assigned to the early Lower Cretaceous by Burckhardt,[79] although no fossils were found. As evidence of their Lower Cretaceous age Burckhardt mentions (1) the occurrence of an upper Aptian ammonite, *Dufrenoya* aff. *D. furcata* (Sowerby), from shale near Campo Morado, about 40 miles west-southwest of Iguala, and (2) their highly folded condition compared with that of the overlying, thick-bedded limestone of the late Lower Cretaceous.

Lower Albian limestone containing *Uhligella mexicana* Burckhardt and *Acanthoplites* juv. cf. *A. bigoureti* (Seunes) are reported from San Gaspar Zumpahuacán in the southern part of the state of México.[80] At the same locality, and at Ayala, Yautepec, and Tetecala in Morelos, and at Grotte de Cacahuamilpa in northernmost Guerrero occur rudistid limestone characterized by *Hippurites mexicanus* Bárcena which Mullerried[81] considers upper Turonian in age, but which Burckhardt[82] suggests may be slightly younger. Limestone from the Cerros de Tepeyac south of the city of Puebla contains *Tepeyacia corrugata* Palmer,[83] which Palmer considers of Turonian age.

EASTERN QUERÉTARO, WESTERN HIDALGO, AND NORTHERN PART OF STATE OF MÉXICO

The middle Albian is represented near Ixmiquilpán, in the Valle del Mesquital, western Hidalgo, by at least 1,000 feet of thin- to thick-bedded limestone containing some nodules and lenses of gray chert. The fossils, according to Mullerried,[84] include *Exogyra texana* (Roemer), *Gryphaea tucumcarii* Marcou, *Toucasia texana* (Roemer), *T. patagiata* (White), *Coalcomana ramosa* (G. Boehm), and *Orbitolina*. Mullerried[85] found 18 specimens of *Coalcomana ramosa* below a

[77] Carlos Burckhardt and F. K. G. Mullerried, "Neue Funde in Jura und Kreide Ost- und Sud-Mexicos," *Eclogae Geol. Helvetiae*, Vol. 29, No. 2 (1936), p. 321.

[78] C. E. Hall, *op. cit.* (1903).

[79] Carlos Burckhardt, *op. cit.* (1930), pp. 157, 158, 200.

[80] Carlos Burckhardt, "Faunas del aptiano de Nazas (Durango), "*Bol. Inst. Geol. México*, Núm. 45 (1925), pp. 12, 39.

[81] F. K. G. Mullerried, "El llamado *Hippurites mexicana* Bárcena," *Anales Inst. Biología México*, T. 1, No. 1 (1930), p. 63.

[82] Carlos Burckhardt, *op. cit.* (1930), p. 235.

[83] R. H. Palmer, *op. cit.* (1928), pp. 10, 46.

[84] F. K. G. Mullerried, "Apuntes paleontológicos y estratigráficos sobre el valle del Mezquital, Estado de Hidalgo," *Anales Escuela Nac. cien. Biologicas*, Vol. 1, Núm. 2 (1939b), Pls. 40–43, pp. 225–54.

[85] *Ibid.*, pp. 235, 241.

bed containing *Toucasia texana*. Elsewhere in Mexico, *C. ramosa* is associated with other rudistids that have been considered of Cenomanian age and are very distinct from the middle Albian rudistids of the Edwards limestone of Texas. If Mullerried's identification is correct, then *C. ramosa* must have such a long range that it is not a reliable stratigraphic marker.

Upper Albian limestone containing the ammonite *Mortoniceras* (*Pervinquieria*) has been found in the Cerro de San Juan near Zimapán, Hidalgo.[86] Rudistid-bearing limestone of probable Cenomanian age has been found near Apaxco in the northern part of the state of México and between Cadereyta and Mineral de las Aguas in Querétaro. The age determination is based on the occurrence of *Monopleura* (*Petalodontia*) *calamitiformis* Bárcena[87] which occurs elsewhere with a large fauna of rudistids and *Nerinea* near Coalcoman in Michoacan.[88] The Turonian has been found near Mineral del Doctor and Cadereyta in Querétaro, near Ixmiquilpán and Zimpapán in Hidalgo, and near Apaxco in the northern part of the state of México. Near Ixmiquilpán the Turonian is represented by calcareous shale and shaly marl containing *Inoceramus labiatus* (Schlotheim) and *I. hercynicus* Petrascheck.[89] At all the other mentioned localities the Turonian is represented by gray, thick-bedded limestone characterized by the presence of *Hippurites mexicanus* Bárcena[90] which Mullerried[91] considers indicative of the upper Turonian.

TEHUACÁN-ZAPOTITLÁN-SAN JUAN RAYA AREA OF SOUTHEASTERN PUEBLA

The areal geology of southeastern Puebla has been studied mainly by Aguilera[92] and Mullerried.[93] According to Mullerried the Jurassic is overlain with apparent conformity by about 300 meters (985 feet) of gray to black marl, shale, and some limestone containing the rudistid, *Monopleura*, and corals that suggest Neocomian age. These beds are particularly well exposed on Cerro La Colmena

[86] Emil Böse, "Algunas faunas cretácicas de Zacatecas, Durango y Guerrero," *Bol. Inst. Geol. México*, Núm. 42 (1923a), p. 41.

[87] Mariano Bárcena, "Datos para el estudio de las rocas mesozoicas de México y sus fósiles característicos," *Bol. Soc. Geog. Mexicana*, T. 3 (1875), pp. 376, 377.
———, "Materiales para le formación de una obra de paleontología mexicana," *Anales de Museo Nac. de México*, I (1877), p. 197.

[88] Carlos Burckhardt, "Étude synthétique sur la mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 206.

[89] Emil Böse, *op. cit.* (1923a), p. 45.

[90] Carlos Burckhardt, *op. cit.* (1930), p. 235.

[91] F. K. G. Mullerried, *op. cit.* (1930), p. 63.

[92] J. G. Aguilera, "Excursion de Tehuacán à Zapotitlán et San Juan Raya," *International Geol. Congress X, Mexico, Guide Excursion* 7 (1906a), 1 map, 27 pages.

[93] F. K. G. Mullerried, "Estudios paleontológicos y estratigráficos en la región de Tehuacán, Puebla," *Anales Inst. Biología México*, T. 4, No. 2 (1933), 8 figs. pp. 79–93.
———, T. 5, No. 1 (1934), pp. 55–80.
———, "The Mesozoic of Mexico and Northwestern Central America," *Proc. Eighth Amer. Scientific Congress*, Vol. 4 (1942a), p. 134.

east of Salinas Grandes. Conformably above follows the Zapotitlán formation which is 200 to 400 meters (655 to 1,310 feet) thick and consists mainly of sandy to shaly marl, but includes some beds of limestone, limestone conglomerate, and sandstone, locally some rock salt and gypsum, and generally about 50 meters of thick-bedded limestone at the top. This formation at several levels has furnished a large fauna of corals, Monopleuras, gastropods, echinoids, and basally a few ammonites,[94] including *Holcodiscus*, *Pulchellia*, and *Olcostephanus* of lower Barremian age. The corals and echinoids merely indicate an upper Neocomian age.[95] Excellent exposures occur on a hill northeast of San Antonio Texcala (de las Salinas) and on Cerro La Colmena east of Salinas Grandes. Conformably above follows the San Juan Raya formation which is 500 to 700 meters (1,640 to 2,295 feet) thick and consists mainly of marl, sandy marl, sandstone, and thin-bedded limestone, but includes some conglomeratic sandstone and limestone conglomerate and, locally, intercalations of salt and gypsum. This formation has furnished a large fauna of echinoids, pelecypods, gastropods, ammonites, and rudistids[96] of Aptian age. Above the San Juan Raya formation lies the Cipiapa limestone,[97] which is many hundreds of meters thick, consists of gray, thick-bedded limestone, limestone conglomerate, and some interbeds of shale, and contains many rudistids. The age of the Cipiapa limestone is not known. Mullerried[98] assigned it questionably to the Albian on the basis of its position directly above beds of Aptian age, but it may well be partly Upper Cretaceous in age. The relationship of the Cipiapa limestone to the San Juan Raya formation has been variously interpreted. Aguilera[99] noted that the Cipaipa limestone is much less folded than the underlying beds, but thought the difference was caused by disharmonic folding. Burckhardt[100] considered that the difference could be explained by an angular unconformity, especially as there is ample evidence for an unconformity at about that stratigraphic position in many parts of southern

[94] Johannes Felix, "Versteineiungen aus der mexicanischen Jura- und Kreide Formation,' *Palaeontographica*, Vol. 37 (1891), pp. 142–72, Pls. 22–26.
Henri Douvillé, "Sur quelques rudistes américains," *Bull. Soc. Géol. France*, 3d Ser., T. 28 (1900), p. 205.
F. K. G. Mullerried, *op. cit.* (1933b), pp. 80–84.
———, *op. cit.* (1934), pp. 55–80.

[95] Carlos Burckhardt, *op. cit.* (1930), p. 160.

[96] H. Nyst and G. Galeotti, "Sur quelques fossiles du calcaire jurassique de Tehuacán au Mexique," *Acad. Roy. Sc. Bruxelles Bull.* 7, Pt. 2 (1840), pp. 212–21.
G. H. Cotteau, "Note sur quelques échinides du terrain crétacé du Mexique," *Bull. Soc. géol. France*, 3d Ser., T. 18 (1890), pp. 292–99.
F. K. G. Mullerried, *op. cit.* (1933b) pp. 84–92.
———, *op. cit.* (1934), pp. 55–63.

[97] J. G. Aguilera, *op. cit.* (1906a), p. 17.

[98] F. K. G. Mullerried, *op. cit.* (1934), p. 73.

[99] J. G. Aguilera, *op. cit.* (1906a), p. 21.

[100] Carlos Burckhardt, *op. cit.* (1930), p. 160.

Mexico. On the contrary, Mullerried[101] asserted that the Cipiapa limestone rests concordantly on the underlying beds and is folded equally with them.

ORIZABA-JALAPA-CORDOBA AREA OF CENTRAL VERACRUZ

Beds of Aptian to Turonian age have been identified in the Orizaba-Cordoba area of central Veracruz. Böse[102] divided the section from bottom to top into the Necoxtla shale, Maltrata limestone, and Escamela limestone, which he correlated, respectively, with the Trinity, Fredericksburg, and Washita groups of Texas. Burckhardt,[103] on the basis of much broader faunal and stratigraphic studies of southern Mexico, contended that Böse had actually included in the Maltrata limestone two different formations of which one occurs above and the other below the Necoxtla shale. This error by Böse is easily understood as the area is strongly folded and faulted, fossils are rather scarce, and the rudistids in the upper limestones require study by specialists. As modified by Burckhardt the section from top to bottom follows.

4. Escamela limestone
   Gray, compact, thick-bedded limestone containing a few chert concretions near base and without intercalations of shale or marl. Thickness, 500 to 600 meters (1,640 to 1,970 feet). Contains a large reef fauna including among others *Chondrodonta* aff. *C. munsoni* Hill, *Coalcomana ramosa* (G. Boehm), *Caprinuloidea? felixi* (G. Boehm), *C.? lenki* (G. Boehm), Nerineas, corals, and Foraminifera including *Orbitolina*. On basis of rudistids Boehm (1898) and Douvillé (1900) placed Escamela limestone in Cenomanian. From same limestone Palmer[104] obtained *Apricardia chavezi* Palmer and *Tepeyacia corrugata* Palmer which he attributed to Turonian.
3. Upper Maltrata limestone
   Gray to black, thin-bedded limestone with bands and nodules of brown chert and intercalations of yellowish shale. Near top contains indistinctly stratified gray dolomite and dolomitic limestone. Thickness of several hundred meters. Age, presumably upper Albian.
2. Necoxtla shale
   Argillaceous, rarely sandy, gray and red shale, containing intercalations of gray brecciated limestone and of gray limestone with chert nodules; becomes more sandy and calcareous near top. Thickness and age unknown, but presumably lower or middle Albian.
1. Lower Maltrata limestone
   Gray to black thin-bedded limestone with bands and nodules of brown chert and intercalations of yellowish shale. Thickness of several hundred meters. Contains *Dufrenoya justinae* (Hill) and *Parahoplites* sp. of upper Aptian age and is correlated with Travis Peak formation of central Texas.

The lower Maltrata limestone differs from all overlying beds and particularly from the upper Maltrata limestone by being strongly folded, which difference, according to Burckhardt,[105] may be explained by the presence of an angular unconformity such as has been recorded near the base of the late Lower Cretaceous at many places in southern Mexico.

[101] F. K. G. Mullerried, *op. cit.* (1934), p. 73.
———, *op. cit.* (1942a), p. 135.

[102] Emil Böse, "Geología de los alrededores de Orizaba con un perfil de la vertiente de la mesa central de México," *Bol. Inst. Geol. México*, Núm. 13 (1899), pp. 5–17.

[103] Carlos Burckhardt, *op. cit.* (1930), pp. 137, 196–99, 236.

[104] R. H. Palmer, "The Rudistids of Southern Mexico," *California Acad. Sci. Occ. Paper 14* (1928), pp. 42, 46, 47.

[105] Carlos Burckhardt, *op. cit.* (1930), p. 196.

HUASTECA AREA OF EASTERN HIDALGO, NORTHERN PUEBLA, AND NORTHERN VERACRUZ

Very little is known about the Lower Cretaceous of the Huasteca area. Near Rancho La Calera in the upper part of the gorge of the Río Vinasco a little south of Huayacocotla, Veracruz, the Neocomian has been identified by Burckhardt[106] as a thin unit of dark gray, calcareous shale containing *Exogyra*. Above follows several hundred feet of black shale and coaly beds, and above that follows over 1,000 feet of compact, gray limestone that contains some gray and reddish marl and shale. These beds are presumably Lower Cretaceous, although no diagnostic fossils have been found.

Near Totolapa a little north of Huauchinango, Puebla, the Upper Jurassic is overlain by a thick mass of compact, gray limestone containing bands and intercalations of black chert. Similar beds southwest of Huauchinango have furnished ammonites of Valanginian and probably Aptian ages.[107]

South of Hacienda Almanza, Veracruz, the Upper Jurassic is overlain by a thick mass of Lower Cretaceous beds.[108] A yellow marl $1\frac{1}{2}$ kilometers south of Plan de Arroyo on the road to Barrancones has furnished a specimen of *Olcostephanus* that probably represents the middle Neocomian. Above follows compact, yellowish gray limestone that west of Cuajilote has furnished ammonites of Barremian or Aptian age, including *Pseudohaploceras*. Still higher follows laminated brown limestone alternating with black shale that near Piedra Grande has furnished ammonites of upper Aptian or lowermost Albian age, including *Columbiceras* and *Acanthoplites*.

Near Zaragoza south of Zacapoaxtla in northern Puebla occurs yellowish gray marly limestone containing upper Aptian ammonites belonging to the genera *Procheloniceras*, *Cheloniceras*, *Puzosia*, and *Aconeceras*.[109] The occurrence of unfossiliferous Lower Cretaceous rocks at many places in northern Puebla has been cited by Hisazumi.[110]

The Lower Cretaceous beds exposed in the Sierra Madre Oriental of the Huasteca area have been called the Tamaulipas limestone,[111] which is typically dense, medium- to thick-bedded limestone, but, judged by the descriptions of outcrops recorded, the formation should be restricted to beds younger than Aptian.

Practically nothing has been published concerning the Upper Cretaceous beds

[106] Carlos Burckhardt, *op. cit.* (1930), p. 92.

[107] *Ibid.*, pp. 93, 137.

[108] *Ibid.*, pp. 93, 94.

[109] Carlos Burckhardt and F. K. G. Mullerried, "Neue Funde in Jura und Kreide Ost- und Sud-Mexicos," *Eclogae geol. Helvetiae*, Vol. 29, No. 2 (1936), p. 317.

[110] Hisakichi Hisazumi, "Informe preliminar acerca de la geología petrolera de la zona comprendida entre Los Ríos Túxpan y Misantla, en los Estados de Puebla y Veracruz," *Anales Inst. Geol. México*, T. 3 (1929), pp. 19–21.

[111] John M. Muir, *Geology of the Tampico Region, Mexico*, Amer. Assoc. Petrol. Geol. (1936), pp. 23, 24, Fig. 12.

along the eastern margin of the Sierra Madre Oriental in the Huasteca area, although Muir[112] has indicated on a map the presence of the same formations as farther north in the mountains west of Tampico, and Arellano[113] lists the same formations for the Poza Rica area about 60 miles east of Huayacocotla.

SOUTHERN OIL FIELDS OF NORTHERN VERACRUZ

In the southern oil fields near Túxpan, Veracruz, the upper part of the Lower Cretaceous consists of rudistid- and miliolid-bearing beds called the El Abra limestone.[114] The Penn Mex' Jardin well No. 35, about 14 miles west-southwest of Túxpan, entered the El Abra limestone at a depth of 2,263 feet and drilled into it for 8,322 feet without reaching its base. The lowest beds penetrated must have been Trinity or older, as a core taken 3,208 feet above the bottom of the well contained *Orbitolina texana* (Roemer). Arellano[115] has published diagrammatic structure sections which show that the El Abra limestone passes westward within 15 to 20 miles into a much thinner limestone of the Tamaulipas facies that is only about 350 meters (1,150 feet) thick from the base of the Agua Nueva formation to the top of the Jurassic. The highest beds of the El Abra limestone are probably lower Cenomanian in age, as limestone fragments blown from two wells contain fossils identified by L. W. Stephenson as *Pecten* (*Neithea*) *roemeri* Hill,[116] which species is characteristic of the Buda limestone of Texas.

The Agua Nueva formation is doubtfully present in the southern oil-field ridge but is present short distances east, according to Muir.[117] About 15 meters (50 feet) is recorded by Arellano[118] in the Poza Rica area about 30 miles south-southwest of Túxpan. The next younger San Felipe formation thickens from a few feet at the northern end of the southern fields to about 60 feet at the southern end[119] and attains about 55 meters (180 feet) in the Poza Rica area.[120] Where the Agua Nueva formation is absent the San Felipe is marked by a basal conglomerate derived from the El Abra limestone. Muir correlates the San Felipe with the uppermost San Felipe of the northern fields because of lithologic resemblances. He notes[121] the presence of a thin remnant of the Méndez formation only at the southern end of the southern oil fields. Arellano notes the presence of about 180 feet of the Méndez formation in the Poza Rica area. The contact with the over-

[112] *Ibid.*, Fig. 12.

[113] A. R. V. Arellano, "La tectonica de la región de Poza Rica, Ver.," *Soc. Geol. Mexicana*, Foll. 4, Serie geotectonica 2 (1942), p. 7.

[114] John M. Muir, *op. cit.* (1936), pp. 40–43.

[115] A. R. V. Arellano, *op. cit.* (1942), p. 7.

[116] John M. Muir, *op. cit.* (1936), p. 41.

[117] *Ibid.*, pp. 52, 53.

[118] A. R. V. Arellano, *op. cit.* (1942), p. 7.

[119] John M. Muir, *op. cit.* (1936), p. 67.

[120] A. R. V. Arellano, *op. cit.* (1942), p. 7.

[121] John M. Muir, *op. cit.* (1936), p. 75.

lying Tamesí formation of Tertiary age is considered to be unconformable.[122] The Tamesí formation consists of gray shale and some red shale, ranges in thickness from 400 feet to a feather-edge, and is absent at the northern end of the oil fields.[123] It is overlain unconformably by the Aragon formation, which Muir[124] considers is "probably equivalent in age to the Wilcox of the Gulf Coast."

NORTHERN OIL FIELDS, OR TAMPICO AREA

The section of Tamaulipas limestone penetrated in the subsurface of the northern fields (Fig. 15) has been well described by Muir[125] and Burckhardt[126] and may be summarized, from top to bottom, as follows.

	Thickness in Feet
7. Limestone, porcellaneous, creamy white, contains white chert. Considered Cenomanian in age	30– 50
6. Limestone, compact, medium dark gray, contains dark brown to black chert. Considered of upper Albian and Cenomanian age	300– 330
5. Limestone, compact, white, contains white chert; considered lower and middle Albian in age	250
4. Limestone, shaly limestone, and calcareous shale, black, locally black chert, bituminous (called Otates horizon by Muir). Considered basal Albian by comparison with fossiliferous outcrops, but probably includes upper Aptian	20– 30
3. Limestone, white to light gray, upper part hard and chalky, traces of white chert locally. Considered Aptian by Muir, but probably also includes Barremian	950–1,050
2. Limestone, white to light gray, locally yellowish, generally coarsely crystalline. Contains ammonites of Berriasian and Valanginian ages	75– 130
1. Sandstone, dark gray, glauconitic, rests on Upper Jurassic marly limestone	5
Total thickness	1,630–1,845

The Neocomian ammonites already referred to were obtained from three wells. In the Corona Petroleum Company's Chocoy well No. 2, about 33 miles northwest of Tampico, the Berriasian is represented by *Berriasella*, *Neocosmoceras*, *Spiticeras*, and *Hemispiticeras*, and the Valanginian is represented by *Thurmannites* and *Valanginites*. In the Mexican Gulf Oil Company's Altamira well No. 11, about 5 miles southwest of the Chocoy well No. 2, the Valanginian, or lower Hauterivian, is represented by *Acanthodiscus* and *Oosterella*.[127] In the Llano de Bustos well No. 1, about 15½ miles south of Tampico, the Berriasian and Valanginian are represented by *Bochianites*, *Platylenticeras*, *Berriasella*, *Neocomites*, *Olcostephanus*, *Valanginites*, and *Himalayites*.[128] In the same well the lower Albian is probably represented by *Acanthoplites bigoureti* (Seunes). Correlations of the subsurface sections are based mainly on comparisons with outcrop sections.

[122] *Ibid.*, p. 90.

[123] *Ibid.*, pp. 90, 108.

[124] *Ibid.*, p. 109.

[125] John M. Muir, *op. cit.* (1936), pp. 15, 32–36.

[126] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 95.

[127] Carlos Burckhardt, *op. cit.* (1930), p. 95.

[128] Carlos Burckhardt and F. K. G. Mullerried, *op. cit.* (1936), p. 317.

In the northern oil fields the formations assigned to the Gulf series of the Upper Cretaceous[129] may be summarily described, from top to bottom, as follows.

	Thickness in Feet
Méndez shale	
8. Shale mainly, calcareous, gray; upper 30 to 100 feet reddish; locally intercalations of soft limestone; many beds of volcanic ash; grades downward into San Felipe formation; overlain disconformably by Tamesí formation	1,000
San Felipe formation	
7. Limestone, thin-bedded, gray and white, alternating with gray laminated shale; changes northward from dominantly calcareous facies to shaly facies	300–400
6. Tuffaceous bed of lilac color; toward northwest is interbedded with limestone	5– 20
5. Limestone, dense, greenish gray, becomes shaly eastward and thin southward	80
4. Limestone, shaly, dark gray, merges eastward into overlying unit, rests concordantly and in places gradationally on Agua Nueva formation	80
Agua Nueva formation	
3. Limestone and shale, interbedded, gray, thins southeastward to a few feet	420
2. Limestone, compact, gray, and black shale partings, generally chert nodules in lower 30 feet	70
1. Shale to shaly limestone, dark gray to black; includes bed of green volcanic material; overlies Tamaulipas limestone with apparent conformity	5– 30

A Turonian species, *Inoceramus hercynicus* Petrascheck, was obtained from a core 33 feet above the base of the Agua Nueva formation in a well near Topila, about 15 miles southwest of Tampico.[130] The age determination of the San Felipe formation in the oil fields is based on its stratigraphic position. Correlation of the Méndez shale with the Taylor and Navarro of Texas is based mainly on studies of the rudistids,[131] Foraminifera,[132] and on regional stratigraphic relationships.[133]

The age of the Tamesí (Velasco) formation is now generally considered Paleocene. It was originally held by Cushman[134] to be Navarro and by Dumble

[129] John M. Muir, *op. cit.* (1936), Fig. 10, pp. 47–53, 62–75, 77, 78, 90.

[130] John M. Muir, *op. cit.* (1936), pp. 50, 53.

[131] W. S. Adkins, "New Rudistids from the Texas and Mexican Cretaceous," *Univ. Texas Bull. 3001* (1930), pp. 77–100.

L. W. Stephenson, "Some Upper Cretaceous Shells of the Rudistid Group from Tamaulipas, Mexico," *Proc. U. S. Nat. Mus.*, Vol. 16, Art. 1 (1922), 15 pls., 28 pp.

———, "The Zone of *Exogyra cancellata* Traced 2,500 Miles," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17 (1933), pp. 1351–61; 1 fig., map.

[132] J. A. Cushman, "Some New Foraminifera from the Velasco Shale of Mexico," *Cushman Lab. Foram. Research Contr.*, Vol. 1, No. 1 (1925), pp. 18–22; 1 pl.

———, "Some Foraminifera from the Méndez Shale of Eastern Mexico," *ibid.*, Vol. 2, Pt. 1 (1926a), pp. 16–24; 2 pls.

———, "The Foraminifera of the Velasco Shale of the Tampico Embayment Area," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10 (1926b), pp. 581–612; 7 pls.

———, "Some Characteristic Mexican Fossil Foraminifera," *Jour. Paleon.*, Vol. 1 (1927a), pp. 147–72, Pls. 23–28.

———, "New and Interesting Foraminifera from Mexico and Texas," *Cushman Lab. Foram. Research Contr.*, Vol. 3, No. 2 (1927b), pp. 111–16.

M. P. White, "Some Index Foraminifera of the Tampico Embayment Area of Mexico," *Jour. Paleon.*, Vol. 2 (1928), pp. 177–215, 280–316.

———, Vol. 3 (1929), pp. 30–58; 2 figs., 10 pls.

[133] John M. Muir, *Geology of the Tampico Region, Mexico*, Amer. Assoc. Petrol. Geol. (1936), pp. 71–74.

[134] J. A. Cushman, *op. cit.* (1926b), pp. 581–82.

and Applin[135] to be early Tertiary. Thalmann[136] pointed out that the Tamesí (Velasco) formation contains a faunal association different from that of the Navarro, has more Tertiary than Cretaceous species, and shows a closer faunal relationship to the Aragón and Chicontepec Eocene faunas of the Tampico district than to the underlying Méndez shale. This viewpoint was concurred with by Barker.[137] Muir[138] reviewed the publications of various paleontologists and concluded that the Tamesí formation is late Cretaceous and probably represents the Danian stage. As evidence for its Cretaceous age he cited the presence of the Foraminifera *Globotruncana* and striate Gumbelinae which are unknown in the Tertiary but are worldwide in the Upper Cretaceous. However, such Foraminifera in the Tamesí formation may have been derived from the Méndez shale by erosion. Muir's assignment of the Tamesí formation to the Danian rather than the late Maestrichtian seems to be based mainly on (1) an opinion that the microfauna is younger than the Navarro formation of Texas and (2) on the presence of fossils of Maestrichtian age in the upper part of the Méndez shale. Stephenson[138a] likewise concurs in the Maestrichtian age of the upper part of the Méndez shale, and its correlation with the upper part of the Navarro group of Texas. Keller[138b] concurred with Muir that the Tamesí formation is of Danian age. However, Glaessner[138c] reported a mixed Tamesí-Midway fauna from the Caucausas region of Russia. Rather conclusive evidence of the early Tertiary age of the Tamesí formation consists of the occurrence of characteristic Tamesí species in beds classed as Midway in the subsurface of the Gulf Coast area of the United States.[138d]

FRONT RANGES WEST OF TAMPICO

The front ranges west of Tampico from the vicinity of Gomez Farias southward to Tamazunchale[139] are composed mainly of thick reef limestone to which

[135] E. T. Dumble and E. R. Applin, "Subsurface Geology of Idolo Island, Vera Cruz, Mexico," *Pan-Amer. Geologist*, Vol. 41, No. 5 (1924), pp. 335–46.

[136] Hans E. Thalmann, "Age of the Velasco," *Proc. Geol. Soc. America* for 1934 (1935), p. 371.

[137] R. W. Barker, "Micropaleontology in Mexico with Special Reference to the Tampico Embayment," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20 (1936), pp. 442–43.

[138] John M. Muir, *op. cit.* (1936), pp. 77, 90–92.

[138a] L. W. Stephenson, "The Larger Invertebrate Fossils of the Navarro Group of Texas," *Univ. Texas Bull. 4101* (1941), p. 29.

[138b] B. M. Keller, "Correlation of the Upper Cretaceous Deposits in Eastern Mexico and in the Western Caucasus," *Bull. Acad. Sci. U. R. S. S.*, No. 5, Ser. Geol. (1937), pp. 837–38.

[138c] M. F. Glaessner, "Studien über Foraminiferen aus der Kreide und dem Tertiar des Kaukasus; I, Die Foraminiferen der ältesten Tertiärschichten des Nordwest-kaukasus," *Problems Paleont.* (Moscow Univ., Lab. Pal. Pub.), Vols. 2–3 (1937), pp. 349–410; 5 pls.

[138d] W. O. George and H. X. Bay, "Subsurface Data on Covington County, Mississippi," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 8 (1935), p. 1158.
W. Storrs Cole, "Stratigraphy and Micropaleontology of Two Deep Wells in Florida," *Florida Dept. Conserv. Geol. Bull. 16* (1938), pp. 23–25, 31–34.

[139] John M. Muir, *op. cit.* (1936), pp. 24, 36–40.
L. B. Kellum, "Similarity of Surface Geology in Front Range of Sierra Madre Oriental to Subsurface in Mexican South Fields," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 14 (1930), pp. 73–91; 3 figs.

the name El Abra has been applied (Fig. 15). In this limestone two main facies have been recognized. In one the fauna consists largely of miliolids and is called the El Abra facies. In the other the fauna consists of rudistids and is called the Taninúl facies. Both facies contain interbeds of the other as well as beds of dense limestone resembling the Tamaulipas limestone. However, the miliolid facies is well developed only in the upper 200 meters of the formation, and the greatest development of the rudistid facies is stratigraphically lower. Heim[140] has plotted the distribution of these facies and shows that in the mountains west of Victoria, Tamaulipas, and south of Xilitla, San Luis Potosí, the El Abra miliolid facies overlies dense, chert-bearing limestone of the Tamaulipas facies. Because of these interfingering and intergrading relationships, Heim has proposed the name Tamabra formation to include the different but approximately contemporaneous facies below the Agua Nueva formation. Kellum[141] also regarded the El Abra and Tamaulipas limestone as facies of a single formation. The thickness of the Tamabra formation, according to Heim,[142] decreases southward from about 1,000 meters (3,280 feet) near Victoria to a few hundred meters at Tamazunchale, San Luis Potosí. Its age apparently ranges from lower Cenomanian to middle Albian, but older beds may be present. Evidence for the lower Cenomanian age consists of the presence of *Pecten* (*Neithea*) *roemeri* Hill in limestones underlying the Agua Nueva formation at Riachuelos about 20 kilometers west of Xicotencatl and near Rascón west of Micos in San Luis Potosí. Evidence for the middle Albian age of the Taninúl rudistid member was obtained by Adkins.[143] From Taninúl tunnel he records among other fossils *Toucasia* cf. *T. texana* (Roemer), *Caprinula* sp.; from Choy Cave, *Eoradiolites* aff. *E. quadratus* Adkins, *Caprinula* sp., *Chondrodonta* cf. *C. munsoni* (Hill); from a quarry 4 kilometers north of Choy Cave, *Caprinula* cf. *C. anguis* Roemer, *Eoradiolites* cf. *E. davidsoni* (Hill), *Toucasia texana* (Roemer), *Lima wacoensis* Roemer, *Kingana* cf. *K. wacoensis* (Roemer). The only significant species listed above are *Toucasia texana, Eoradiolites* aff. *E. quadratus*, and cf. *E. davidsoni*. Species of *Chondrodonta* similar to *C. munsoni* (Hill) range through the Fredericksburg and Washita. Muir[144] correlates the Taninúl member with the Edwards limestone of Texas and the El Abra miliolid member with the Buda and probably some Georgetown of Texas. The correlation seems apt.

The Agua Nueva formation cropping out along the flanks of the front ranges west of Tampico[145] consists of black, laminated, thin-bedded limestone that weathers deep brown and is interbedded with gray to buff shales and becomes

[140] Arnold Heim, "The Front Ranges of Sierra Madre Oriental, Mexico, from Ciudad Victoria to Tamazunchale," *Eclogae Geol. Helvetiae*, Vol. 33, No. 3 (1940), Pl. 16, pp. 321, 324–26.

[141] L. B. Kellum, *op. cit.* (1930), p. 89.

[142] Arnold Heim, *op. cit.* (1940), p. 326.

[143] W. S. Adkins, "New Rudistids from the Texas and Mexican Cretaceous," *Univ. Texas Bull. 3001* (1930), p. 82.

[144] John M. Muir, *op. cit.* (1936), p. 36.

[145] John M. Muir, *Geology of the Tampico Region, Mexico,* Amer. Assoc. Petrol. Geol. (1936), pp. 45–49.

more calcareous westward. It rests conformably on the Tamabra limestone, with the possible exception of an exposure 18 kilometers south-southwest of Tamazunchale, San Luis Potosí.[146] In some places it appears to grade upward into the San Felipe formation,[147] but in many places it is absent owing to erosion or to overlap of younger formations.[148] Thicknesses recorded range from 24 feet at the south end of the Sierra del Abra to 130 feet near Nuevo Morelos. The Turonian age of most of the formation has been based mainly on the presence of *Inoceramus labiatus* (Schlotheim) and *I. hercynicus* Petrascheck.[149] However, Adkins[150] records a Cenomanian ammonite, *Mantelliceras* aff. *M. couloni* (D'Orbigny) from 10 feet above the base of the Agua Nueva formation in a road cut 18 kilometers southwest of Tamazunchale.

The San Felipe formation cropping out west of Tampico consists of gray, yellowish-weathering, thin- to medium-bedded limestone alternating with smaller amounts of gray shale and becomes more calcareous westward. In many places it grades downward into the Agua Nueva formation, but at other places, as along the eastern margins of the Sierras del Abra, Cucharas, and Colmena, it overlaps onto the Tamabra limestone.[151] Its thickness on the outcrop ranges from about 400 meters (1,312 feet) to the vanishing point depending on the overlap relationships of itself and of the overlying Méndez shale,[152] but the average thickness is 700 to 800 feet. These relationships prove that the front ranges west of Tampico originated in early Upper Cretaceous time, emerged from the sea as islands at the end of Agua Nueva (Turonian) time, underwent erosion involving local removal of the Agua Nueva formation, and part of the Tamabra limestone, and then gradually sank beneath the sea during San Felipe and early Méndez time. The age of the San Felipe formation in this area is based partly on its superposition on the Agua Nueva formation containing the characteristic Turonian species *Inoceramus labiatus* (Schlotheim) and partly on fossils collected by Stephenson[153] from the upper part of the San Felipe formation on the Chocoy and Manuel haciendas, which are about 71 and 81 kilometers, respectively, northwest of Tampico. From these localities Stephenson lists *Balanocrinus mexi-*

[146] *Ibid.*, p. 32.

[147] *Ibid.*, p. 46.
Arnold Heim, *op. cit.* (1940), p. 328.

[148] John M. Muir, *op. cit.* (1936), Fig. 12, pp. 61, 62.
Arnold Heim, *op. cit.* (1940), Pl. 16, p. 328.

[149] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 221.
John M. Muir, *op. cit.* (1936), pp. 45, 46.

[150] John M. Muir, *op. cit.* (1936), p. 53.

[151] John M. Muir, *op. cit.* (1936), pp. 61, 62.
Arnold Heim, *op. cit.* (1940), Pl. 16, pp. 328, 329.

[152] L. B. Kellum, *op. cit.* (1930), p. 88.

[153] L. W. Stephenson, "Some Upper Cretaceous Shells of the Rudistid Group from Tamaulipas, Mexico," *Proc. U. S. Nat. Mus.*, Vol. 16, Art. 1 (1922). 28 pp., 15 pls.
Carlos Burckhardt, *op. cit.* (1930), p. 229.
John M. Muir, *op. cit.* (1936), p. 59.

canus Springer, *Inoceramus* of large size, *Ostrea plumosa* Morton, *Ostrea congesta* Conrad (?), *Sauvagesia degolyeri* Stanton (?), and *Durania manuelensis* Stephenson. According to Stephenson, the presence of *Ostrea congesta* Conrad (?) and the large Inocerami furnish a correlation with the Austin chalk, and the presence of *Ostrea plumosa* Morton shows an age not older than the upper part of the Austin chalk. Further evidence for correlation with the Austin chalk is furnished by the discovery of a rudistid resembling *Sauvagesia degolyeri* Stanton in the Austin chalk of Travis County, Texas.[154]

The Méndez formation cropping out in the synclines between and east of the front ranges[155] consists mainly of gray to greenish gray shale and marl, but south of the Río Tampaon its upper part contains much reddish shale and locally some sandy beds which may be equivalent to the Cárdenas formation farther west. Thin layers of volcanic ash occur throughout. The beds become somewhat harder toward the west. The Méndez grades downward into the San Felipe formation and is overlain disconformably by the Tamesí formation. Thicknesses of 700 to 1,400 feet, or more, have been reported. Evidence for the Campanian-Maestrichtian age of the Méndez formation has been discussed thoroughly by Muir.[156]

CÁRDENAS-CANOAS-TAMASOPO AREA OF SOUTHEASTERN SAN LUIS POTOSÍ

The Cretaceous exposed in the Cárdenas-Canoas-Tampasopo area (Fig. 15) ranges in age from Turonian to Maestrichtian and comprises facies very different from those in the Tampico area.[157] The section from Cárdenas eastward to Tamasopo has been described by Heim as follows.

Upper Cárdenas beds, 2,000 m:

13. Yellow limestone, interbedded with marls.
12. Greenish marls, resembling Méndez beds, 500 m.
11. Sandstone and sandy-marly limestone with oyster beds: *Gryphaea vesicularis* Lan., *G. costata* Say, *Ostrea gigantica.*
10. Well-bedded limestone with marls.
    (The relations of the above beds to the underlying strata are obscured by folding and lack of exposures.)

9a. Cárdenas Red Clay, several hundred meters.
9b. Red and green clay-shale, resembling Tamesí beds.

[154] W. S. Adkins, *op. cit.* (1930), p. 99.

[155] John M. Muir, *op. cit.* (1936), pp. 68–76.
Arnold Heim, *op. cit.* (1940), p. 329.
Carlos Burckhardt, *op. cit.* (1930), p. 229.

[156] John M. Muir, *op. cit.* (1936), pp. 71–74, 76.

[157] Emil Böse, "[Excursion] de San Luis Potosí à Tampico," *International Geol. Congress X, Mexico, Guide Excursion No. 30* (1906a). 16 pp.
———, "La fauna de moluscos del senoniano de Cárdenas, San Luis Potosí," *Bol. Inst. Geol. México,* Núm. 24 (1906b). 95 pp.
Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), pp. 77, 78, 97, 100, 179.
Carlos Burckhardt, *op. cit.* (1930), pp. 231–34, 251, 252.
John M. Muir, *op. cit.* (1936), pp. 60, 61.
L. W. Stephenson, "The Larger Invertebrate Fossils of the Navarro Group of Texas," *Univ. Texas Bull. 4010* (1941), p. 36.
Arnold Heim, *op. cit.* (1940), pp. 331–33.

Lower Cárdenas beds, about 1,300 m:
8. Very fossiliferous marls and sandstones with corals, *Coralliochama g.-boehmi* Böse, *Exogyra costata* Say, etc.
7. Hard, gray, calcareous sandstone with gastropods: *Conus*, *Turritella*, etc. (Gap, covered by caliche.)
6. Marls and nodular limestones full of oysters: *Gryphaea*.
5. Gray shale with limestone, 200–300 m.
4. Marls and nodular limestones full of oysters: *Cardium*, *Pholas*, etc.
3. Gray shale with beds up to 1 m. thick of yellow limestone full of *Pseudorbitoides*, 100–200 m.

Méndez marls:
2. Gray, more or less sandy shale, 200–300 m.
1. Conglomerate, 1 m.

Tamasopo limestone.

A generalized section of the Cárdenas area described by Mullerried,[158] from top to bottom, follows.

	Thickness in Meters	*Thickness in Feet*
7. Sandy marl alternating with soft sandstone, in part reddish; at the base contains small bivalves and gastropods	300	985
6. Sandy marl alternating with sandstone and limestone, gray, contains *Coralliochama*, *Biradiolites*, oysters, corals, *Actaeonella*, many bivalves	200	655
5. Sandy marl alternating with sandstone and some limestone, contains oysters, radiolitids, corals, *Lithothamnium*	300	985
4. Sandy marl alternating with sandstone and limestone, contains orbitoids, echinoids, corals, *Exogyra*, radiolitids, bivalves, gastropods; basal part has furnished *Sphenodiscus pleurisepta* (Conrad)	200	655
3. Sandy marl and some beds of sandstone, contains *Inoceramus*	50	165
2. Marl	100	330
1. Limestone and marly limestone, contains rudistids, bivalves, echinoids, corals, miliolids	800	2,625
	1,950	6,370+

In the foregoing section, unit 1 corresponds with the Tamasopo formation, unit 2 with the Méndez shale, and the overlying units with the Cárdenas formation.

A detailed section of the upper part of the Cárdenas formation was measured by Bruce Wade in 1923 while working for the Compañia de Petroleo Mercedes, S. A. Subsequently, the description of the section was transmitted to L. W. Stephenson by William Baker, then chief geologist of the company. It is published herein with the permission of the Standard Oil Company of New Jersey. The section extends from the head of Cañon Cañada, about 2 miles southeast of Cárdenas, to a spring 225 feet north of the culvert at Kilometer Post 416.3 on the Tampico-San Luis Potosí Railroad, about 1 mile east of Cárdenas.

SECTION OF CÁRDENAS FORMATION EAST AND SOUTHEAST OF CÁRDENAS
(Measured by Bruce Wade)

Unit	*Feet*
103. Sandstone, coarse-grained, gray, and small clay pebbles	32.0
102. Shale, red	48.6
101. Sandstone, coarse-grained, brownish gray	6.3
100. Shale, sandy, red and gray	54.0
99. Shale, red	27.0
98. Shale, red and gray	28.8

[158] F. K. G. Mullerried, "La Sierra Madre Oriental en Mexico," *Revista Mexicana de Geografía*, T. 2 (1941), p. 29.

Unit	*Feet*
97. Shale, white, and pink sandstone	2.2
96. Shale, red	28.8
95. Shale and sandstone, compact	11.7
94. Shale, sandy, red	6.7
93. Sandstone, semi-indurated, gray	7.7
92. Shale, red and reddish brown, partly covered	315.0
91. Sandstone, coarse-grained, brownish gray	2.7
90. Shale, red and gray, partly covered	116.4
89. Shale and sandstone, red, gray, and yellow, semi-indurated	83.3
88. Shale, red and gray, mostly covered	114.6
87. Limestone, bearing many radiolitids	16.7
86. Shale, sandy, partly covered	94.8
85. Sandstone, gray	2.7
84. Covered. Probably shale	24.2
83. Sandstone, hard, gray	0.9
82. Covered. Probably sandy shale	81.8
81. Sandstone, calcareous, hard, brown and gray	2.7
80. Sandstone and shale, calcareous, brown; contains many gastropods and some pelecypods	19.8
79. Covered. Probably shale	59.4
78. Shale, calcareous	37.8
77. Limestone, shaly	12.0
76. Covered. Probably shale	61.3
75. Limestone, gray	1.8
74. Shale, partly covered	60.4
73. Sandstone, calcareous, gray	9.0
72. Covered. Probably shale	81.8
71. Sandstone, calcareous, pinkish; fragments of *Ostrea* and *Lima*	21.3
70. Shale and limestone, sandy, partly covered	102.3
69. Shale and limestone; contains large rudistids	18.0
68. Sandstone, hard, gray	0.9
67. Shale, calcareous, partly covered; contains many Nerineas and Actaeonellas	94.6
66. Limestone and shale	12.9
65. Covered. Probably shale	28.0
64. Sandstone, coarse-grained, brown	28.8
63. Shale, limestone, and sandstone, partly covered; contains Actaeonellas and large rudistids, including *Coralliochama*	155.8
62. Limestone, sandy, brown	2.5
61. Shale containing layers of gray, calcareous sandstone 1 to 12 inches thick	130.7
60. Shale and gray, sandy, thin-bedded limestone	24.9
59. Shale, sandy, partly covered	28.3
58. Sandstone, thin-bedded, hard, brownish gray	10.3
57. Shale and sandstone, partly covered; contains *Ostrea*	97.1
56. Sandstone, calcareous, hard, brown; contains *Exogyra*	3.6
55. Sandstone and shale, brown; contains *Exogyra costata* Say	72.0
54. Shale and sandstone	79.2
53. Shale, calcareous, yellow	70.0
52. Limestone, rudistid-bearing	20.0
51. Limestone, sandy, hard, white and brown; contains many gastropods and some rudistids	16.2
50. Covered. Probably shale and sandstone	84.6
49. Sandstone, massive, semi-indurated, gray	25.2
48. Covered. Probably shale and sandstone	162.4
47. Sandstone	0.9
46. Shale, partly covered; thin beds of sandstone and limestone in upper 50 feet	162.9
45. Limestone, brownish pink	1.3
44. Covered. Probably shale	31.5
43. Limestone containing algal-like bodies	80.1
42. Shale, gray and pink; many pelecypods in upper 20 feet	301.3
41. Sandstone, semi-indurated, yellow and gray	7.4
40. Covered. Probably shale	62.3
39. Shale and sandstone, yellow; abundant bryozoans	16.7
38. Sandstone, calcareous, hard; abundant bryozoans	8.3
37. Shale, sandy; many pelecypods and bryozoans	39.0

Unit	Feet
36. Sandstone, calcareous, hard	0.9
35. Sandstone and shale	16.7
34. Sandstone, calcareous, hard, brown	1.8
33. Sandstone, soft, blue and gray	33.4
32. Shale, yellow and gray	314.3
31. Shale and limestone	30.6
30. Covered. Probably shale	94.8
29. Limestone and shale	26.9
28. Limestone, orbitoidal, hard, gray	4.1
27. Covered. Probably shale	24.9
26. Limestone, orbitoidal, grayish brown	2.7
25. Shale and thin layers of limestone	94.8
24. Limestone, brown	3.7
23. Covered. Probably shale. Two beds of orbitoidal limestone near base	79.2
22. Shale, sandy, brownish; contains pelecypods	101.0
21. Limestone, orbitoidal, brown and gray	13.6
20. Covered. Probably shale and limestone	38.5
19. Limestone, orbitoidal	8.3
18. Covered. Probably shale and limestone	25.1
17. Limestone, orbitoidal	11.1
16. Shale and limestone	55.9
15. Limestone, orbitoidal, brown	10.3
14. Shale and thin layers of orbitoidal limestone	103.1
13. Covered. Probably shale	37.8
12. Limestone, brown	0.8
11. Covered. Probably shale and limestone	74.8
10. Limestone, sandy, poorly exposed	16.3
9. Shale; contains many pelecypods and gastropods that Bruce Wade correlates with Coon Creek formation in Tennessee	35.6
8. Limestone, white to brownish; contains rudistids and gastropods	28.3
7. Sandstone and shale, partly covered	67.9
6. Sandstone, calcareous, very hard	0.8
5. Shale and sandstone, poorly exposed	67.9
4. Limestone, orbitoidal, brownish	19.7
3. Shale and a few beds of limestone	266.6
2. Shale, partly covered, sandy beds near top; contains pelecypods, *Baculites*, and orbitoids	397.3
1. Limestone, orbitoidal, hard, white and pink	21.5
Total thickness in feet	5,570.0

The Tamasopo limestone is thick-bedded, dense, brittle, light buff; weathers whitish to light buff; contains some shale layers, particularly in its upper few hundred feet; bears rudistids; and has an estimated thickness of 1,000 to 2,000 meters (3,280 to 6,560 feet). It has been identified as far east as Xilitla, Llanito, and near Rascón in San Luis Potosí, and as far north as El Capulín in southwestern Tamaulipas. Its western and southern extent is not known. Near Xilitla in extreme southeastern San Luis Potosí it grades downward into the Agua Nueva formation through several hundred meters of beds that Heim[159] includes in the San Felipe formation. East of Rascón and Llanito near the Río Frio (Gallinas) in San Luis Potosí it grades laterally in a few miles into the Agua Nueva and San Felipe formations.[160] At Canoas it is overlain by the Méndez shale. The regional

[159] Arnold Heim, "The Front Ranges of Sierra Madre Oriental, Mexico, from Ciudad Victoria to Tamazunchale," *Eclogae geol. Helvetiae*, Vol. 33, No. 2 (1940), pp. 327, 328.

[160] *Ibid.*, p. 331.
John M. Muir, *Geology of the Tampico Region, Mexico*, Amer. Assoc. Petrol. Geol. (1936), p. 61.

stratigraphic relationships indicate that the Tamasopo limestone is equivalent to the upper part of the Agua Nueva formation and the entire San Felipe formation. Muir[161] indicates that part of the Tamasopo formation may be Campanian in age and equivalent to the lower part of the Méndez shale of the Tampico area, but this possibility seems unlikely because of the occurrence of a conglomerate at the base of the Méndez shale near Canoas. The presence of *Coralliochama* in the upper part of the Tamasopo limestone[162] is not evidence of an age as young as Campanian, as the type of the genus occurs in beds of Turonian age.[163] The fauna of the Tamasopo formation has not been studied. Böse and Cavins[164] record *Sauvagesia* in its lower and middle parts, and *Coralliochama* and *Biradiolites* in its upper part. Northwest of Llanito the uppermost beds of the formation furnished *Acteonella burckhardti* Böse, which characterizes beds of basal Coniacian age near Zumpango del Río, Guerrero.[165] However, the range of the species is not known.

The 500 to 1,000 feet of Méndez shale cropping out near Canoas has furnished Foraminifera indicating Navarro or uppermost Taylor age.[166]

The Cárdenas formation[167] has been examined, and its enormous thickness confirmed by several geologists, but details of the entire section have not yet been published. Its large fauna includes such diagnostic Navarro markers as *Exogyra cancellata* Stephenson, *E. costata* Say, and *Sphenodiscus* cf. *S. lenticularis* Owen.[168] Its Navarro age has been confirmed by studies of the Foraminifera,[169] but its highest beds may be Tertiary in age, as suggested by Mullerried.[170]

[161] *Ibid.*, pp. 20, 73.

[162] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), p. 77.

[163] F. M. Anderson and G. D. Hanna, "Cretaceous Geology of Lower California," *Proc. California Acad. Sci.*, 4th Ser., Vol. 23, No. 1 (1935), pp. 7, 14, 18, 31.

[164] Emil Böse and O. A. Cavins, *op. cit.* (1927), p. 77.

[165] John M. Muir, *op. cit.* (1936), p. 61.

[166] *Ibid.*, pp. 72, 73.

[167] Emil Böse, "[Excursion] de San Luis Potosí a Tampico," *International Geol. Congress X, Mexico, Guide Excursion No. 30* (1906a). 16 pp., 6 figs.
———, "La fauna de moluscos del senoniano de Cárdenas, San Luis Potosí," *Bol. Inst. Geol. México*, Núm. 24 (1906b). 95 pp.
Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 232, 251.
Arnold Heim, "The Front Ranges of Sierra Madre Oriental, Mexico, from Ciudad Victoria to Tamazunchale," *Eclogae geol. Helvetiae*, Vol. 33, No. 2 (1940), p. 332.

[168] L. W. Stephenson, "The Zone of *Exogyra cancellata* Traced 2,500 Miles," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17 (1933), pp. 1351–61; 1 fig., map.
John M. Muir, *op. cit.* (1936), pp. 72, 73.
Carlos Burckhardt and F. K. G. Mullerried, "Neue Funde in Jura und Kreide Ost- und Sud-Mexicos," *Eclogae geol. Helvetiae*, Vol. 29, No. 2 (1936), p. 321.

[169] R. Wright Barker and T. F. Grimsdale, "Studies of Mexican Fossil Foraminifera, Pt. III. A New Alveolinellid from the Upper Cretaceous of Mexico," *Annals and Mag. Nat. Hist.*, Ser. 10, Vol. 19 (1937), pp. 173–76.

[170] F. K. G. Mullerried, *op. cit.* (1936), p. 39.

WEST-CENTRAL SAN LUIS POTOSÍ

Limestones near Charcas in west-central San Luis Potosí have furnished the ammonites *Distoloceras* and *Neocomites*, which indicate a Valanginian or lower Hauterivian age.[171] Dark gray, chert-bearing limestone on Cerro de San Pedro, about 12 miles northeast of the city of San Luis Potosí, have furnished the ammonites *Astieridiscus* and *Olcostephanus*, whose association is evidence of a Hauterivian age.[172] About 20 miles east of the city of San Luis Potosí, in the mountains near Barbosa, occur rudistid-bearing limestones that have furnished *Hippurites mexicanus* Bárcena and *Radiolites mendozae* Bárcena. Mullerried[173] considers *H. mexicanus* to be upper Turonian in age, and MacGillavry[174] states that the Hippuritinae did not come into being until upper Turonian time.

SOUTHEASTERN ZACATECAS

At Pinos, Zacatecas, the upper Aptian, or lower Albian, is represented by beds containing *Parahoplites*. Older Cretaceous beds are probably present, as the late Jurassic also occurs at the same locality.[175]

Cretaceous rocks exposed in a small, east-west trending mountain south of Noria de Angeles, about 20 miles west-northwest of Pinos, have been studied by Burckhardt.[176] The northern base of the mountain exposes gray to black sandstone, shale, and shaly limestone probably early Upper Cretaceous in age. These are overlain on the upper part of the mountain by southward-dipping, dark gray, well bedded limestone containing intercalations of black chert. From the summit were obtained ammonites of upper Albian age,[177] including *Hysteroceras*, *Hamites* aff. *H. charpentieri* Pictet, and *Ancyloceras* (?).

FRESNILLO DISTRICT OF CENTRAL ZACATECAS

In the small mountain extending north-northeast from Fresnillo occurs dark gray, distinctly bedded limestone containing intercalations of chert[178] and am-

[171] Roberto Fernández, "La industria minero-metalurgica en la Estado de San Luis Potosí," *Bol. Minero México Dept. de Minas*, T. 14, Núm. 4 (1922), p. 492, Figs. 10–12.
Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 136.

[172] G. I. Finlay, "Geology of the San Pedro District, San Luis Potosí, México," *Columbia Univ. School Mines Quart.*, Vol. 25 (1903), p. 60.
Roberto Fernández, *op. cit.* (1922), p. 489, Fig. 3.
Carlos Burckhardt, *op. cit.* (1930), p. 137.

[173] F. K. G. Mullerried, "El llamado *Hippurites mexicana* Bárcena," *Anales Inst. Biología México*, T. 1, No. 1 (1930), p. 63.

[174] H. J. MacGillavry, "Geology of the Province of Camagüey, Cuba, with Revisional Studies in Rudist Paleontology," *Geog. Geol. Mededeel. Phys.-Geol. Reeks*, No. 14 (1937), pp. 101, 105.

[175] Carlos Burckhardt, *op. cit.* (1930), pp. 81, 137.

[176] *Ibid.*, pp. 171, 240.

[177] Emil Böse, "Algunas faunas cretácicas de Zacatecas, Durango y Guerrero," *Bol. Inst. Geol. México*, Núm. 42 (1923a), p. 41.

[178] Carlos Burckhardt, *op. cit.* (1930), p. 170.

monites of upper Albian age. Among these, Böse[179] has identified *Turrilites* of the group of *T. costatus* Lamarck, *T.* cf. *T. scheuchzeri* Böse, *Hysteroceras*, and *Hamites* cf. *H. venetzianus* Pictet.

SIERRA DE CATORCE, NORTHERN SAN LUIS POTOSÍ

On the flanks of the Sierra de Catorce the Upper Jurassic is overlain by a considerable thickness of Lower Cretaceous limestone.[180] The lower part of the Neocomian is represented by the Taraises formation, which comprises two members. The lower member consists of dark gray, medium- to thick-bedded limestone and contains Valanginian ammonites. The upper member consists of medium- to thin-bedded limestone, marl, and fine-grained sandstone, has limonite concretions, weathers reddish yellow, and contains Hauterivian ammonites. Burckhardt[181] considers that the Valanginian is represented by *Olcostephanus potosina* Castillo and Aguilera[182] and the lower Hauterivian by *Thurmmanites* aff. *T. campylotoxus* (Uhlig), *Crioceras* group of *C. duvali* Leveille, *Olcostephanus* aff. *O. klaatschi* Wegner, and *O.* cf. *O. jeannoti* D'Orbigny. Above follows a black, compact limestone containing Barremian ammonites, including *Crioceras nolani* Kilian, *Paracrioceras*, *Barremites* aff. *B. difficile* (D'Orbigny), and *Pseudohaploceras*. Burckhardt considered these ammonites as lower Barremian in age, probably on the identification of *Crioceras nolani*, as the genera are not so narrowly restricted. The upper part of the Lower Cretaceous consists of gray, compact limestone containing bands and nodules of black chert, and the upper Albian ammonite *Hysteroceras aguilerae* (Böse).[183]

SOUTHWESTERN TAMAULIPAS AND SOUTHERNMOST NUEVO LEÓN

The Lower Cretaceous rocks of southwestern Tamaulipas and southern Nuevo León (Fig. 14) have been called the Tamaulipas or Tamabra limestone by petroleum geologists, apparently because there was no economic need to make smaller subdivisions, but the section could readily be divided into a number of formations. The Tamaulipas limestone near Huizachal and in Cañón del Novillo west of Victoria, according to Heim,[184] is about 1,000 meters (3,280 feet) thick and consists mainly of light to dark gray, dense, thick-bedded limestone with a little dark chert, but at its base contains some marly limestone of lower Neo-

[179] Emil Böse, *op. cit.* (1923a), p. 41.

[180] C. L. Baker, "General Geology of the Catorce Mining District," *Amer. Inst. Min. Met. Eng.*, Vol. 66 (1922), p. 45.
Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 78, 136, 171.

[181] *Ibid.*, p. 136.

[182] Antonio Castillo and Jose G. Aguilera, "Fauna fósil de la Sierra de Catorce, San Luis Potosí," *Bol. Com. Geol. México*, Vol. 1 (1895), Pl. 7, Fig. 2; Pl. 12, Figs. 1, 2.

[183] Emil Böse, *op. cit.* (1923a), pp. 40, 167, Pl. 9, Fig. 34.

[184] Arnold Heim, "The Front Ranges of Sierra Madre Oriental, Mexico, from Ciudad Victoria to Tamazunchale," *Eclogae geol. Helvetiae*, Vol. 33, No. 2 (1940), pp. 321, 322, Figs. 2, 3.

comian age, near its top some miliolid limestone probably upper Albian in age, and at the top 80 to 100 meters of black, thin-bedded limestone that is possibly earliest Upper Cretaceous in age. C. L. Baker, in Muir,[185] noted that the top of the Tamaulipas limestone in Cañón del Novillo consists of 175 feet or more of light blue, laminated, flaggy, thin-bedded limestone containing considerable black chert as layers and nodules. In Cañón del Novillo the Otates beds[186] may be represented by 20 feet of dark, thinly laminated, thin-bedded limestone underlying about 350 feet of light gray, dense, medium- to thick-bedded limestone containing *Kingena wacoensis* (Roemer).

The Lower Cretaceous rocks near Miquihuana, Tamaulipas, are much better known.[187] The most complete section may be described, from top to bottom, as follows.

SECTION IMMEDIATELY WEST-NORTHWEST OF MIQUIHUANA ON WEST FLANK OF MIQUIHUANA ANTICLINE[188]
(Measured by L. G. Putnam and L. C. Reed)

	Thickness in Feet
12. Limestone, medium to thick-bedded, fine-grained to lithographic, light brown to black; some beds dolomitic; rudistids and miliolids in lower beds	197
11. Limestone, dolomitic, crystalline, light to dark gray	245
10. Limestone as above, but with some beds of light to dark brown, fine-grained, thin-bedded limestone carrying miliolids	476
9. Limestone, thin- to medium-bedded, light gray to black, crystalline, dolomitic, hard to soft and decomposed	508
8. Limestone as above grading downward and interbedding with lithographic, dark gray to black, light to dark brown, fine-grained to crystalline limestone. Black limestone carries nodular and lenticular, coal-black, vitreous chert. Rudistids replaced by groups of quartz crystals	738
7. Limestone, medium-bedded, fine- to dense-textured, light to dark brown, with rolled rudistids	395
6. Limestone, alternating whitish gray and light to dark gray, crystalline; fine- to coarse-grained; some beds decomposed. Base of zone of *Orbitolina texana* (Roemer) about 100 feet from top	985
5. Limestone as below, but with echinoid spines	98
4. Limestone, thin-bedded, fine- to dense-textured, light to dark gray to dove-colored, carrying light to dark gray chert in nodules and thin lenses	280
3. Limestone as above but without chert	82
2. Limestone, thin-bedded to shaly, light gray; marly and silty shales	66
1. Shale, massive, hard, gray to black, ferruginous, calcareous, spheroidal weathering, grading downward into marly and silty shales. Basal conglomerate. Angular unconformity at base	131
Total thickness	4,201

The foregoing beds rest with angular unconformity on about 820 feet of red-beds of probable early Upper Jurassic age which rest with angular unconformity on talc schist. The lower 657 feet of the Cretaceous section, consisting of dove-colored, thin-bedded limestone and calcareous shale, is probably entirely Neo-

[185] John M. Muir, *Geology of the Tampico Region, Mexico*, Amer. Assoc. Petrol. Geol. (1936), p. 48.

[186] John M. Muir, *op. cit.* (1936), p. 28.

[187] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 155-57.
R. W. Imlay, "Lower Neocomian Fossils from the Miquihuana Region, Mexico," *Jour. Paleon.*, Vol. 11, No. 7 (1937b), pp. 554-57.

[188] *Ibid.*, p. 556.

comian in age, as the basal 200 feet contains fossils of Valanginian age. Its lithologic appearance and stratigraphic position are similar to those of the Taraises formation, and it probably should be recognized by the same name. The overlying 885 feet of gray, medium- to thick-bedded limestone, as high as the lowest occurrence of *Orbitolina texana* (Roemer), must represent the Aptian but may include some Barremian at the base. The highest 2,659 feet of rudistid-bearing limestone is similar to the El Abra limestone except for the presence of dolomitic beds and must be mainly of Albian age. Of this 2,659 feet, the upper 918 feet consists of medium- to thick-bedded miliolid limestone comparable in position with miliolid beds at the top of the El Abra limestone, and therefore may be upper Albian in age. The lower 1,741 feet consist of thin- to medium-bedded rudistid limestone comparable with the Taninúl member of the El Abra limestone. The contact with the Upper Cretaceous is not exposed.

An even thicker section was measured by L. C. Reed and E. R. Silliman on the west slope of Cerro de Peña Nevada near San Lazaro, Nuevo León,[189] about 24 miles north-northwest of Miquihuana. The generalized section, from top to bottom, follows.

	Thickness in Feet
4. Limestone, medium-bedded, buff, bearing rudistids	1,148
3. Limestone, covered or poorly exposed	1,804
2. Limestone, massive, sugary textured, dolomitic, dark gray, with strong odor, fossiliferous near top	1,410
1. Limestone, thin- to medium-bedded, dove-colored, darker near top; cherty beds begin about 1,214 feet above base. Probably mainly Neocomian in age	3,116
Total thickness	7,478

Burckhardt[190] has shown that the vicinity of Miquihuana was an island during Upper Jurassic time and was not submerged until the Valanginian stage of the early Lower Cretaceous. At Miquihuana beds of Valanginian age rest on red beds of probable Divesian age. On the west flank of the San Lazaro anticline, about 0.6 mile south of the pass on the San Lazaro-Zaragosa trail, the Valanginian beds rest on limestone of middle Kimmeridgian age.[191] About one mile north of San Lazaro they rest on gypsum on lower Kimmeridgian age.[192] At Rancho Molino near Peregrina they rest on upper Kimmeridgian beds containing *Rasenia*.[193] West-southwest of Huizachal they rest on lower Portlandian beds containing *Kossmatia*.[194]

[189] R. W. Imlay, "Upper Jurassic Ammonites from Mexico," *Bull. Geol. Soc. America*, Vol. 50 (1939a), p. 15.

[190] Carlos Burckhardt, *op. cit.* (1930), pp. 86–90.

[191] R. W. Imlay, "Lower Neocomian Fossils from the Miquihuana Region, Mexico," *Jour. Paleon.*, Vol. 11, No. 7 (1937b), p. 555.

[192] *Ibid.*, p. 557.

[193] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 87, 88.
John M. Muir, *Geology of the Tampico Region, Mexico*, Amer. Assoc. Petrol. Geol. (1936), p. 13.

[194] Carlos Burckhardt, *op. cit.* (1930), pp. 88, 89.

Beds of Berriasian and Hauterivian ages have not been identified in southern Nuevo León and southwestern Tamaulipas. Near Miquihuana and San Lazaro the basal Cretaceous beds contain gigantic *Thurmannites*, probably middle Valanginian in age. These are overlain by beds containing *Rogersites*, *Olcostephanus*, *Valanginites*, and some *Thurmannites*, which are of undoubted upper Valanginian age.[195] West-southwest of Huizachal, Tamaulipas, the basal Cretaceous beds contain *Rogersites*, *Neocomites*, *Polyptychites*, and *Blanfordiceras*.[196] of Valanginian age. An *Olcostephanus* of probable Valanginian age was obtained near San Antonio Peña Nevada, Nuevo León. Limestones cropping out east of the road about halfway between Miquihuana and Aramberri north of the Carmen Valley have furnished ammonites identified by Burckhardt[197] with species of *Pseudohaploceras* and *Desmoceras* juv. of the group of *D. strettostoma* Uhlig (equals *Barremites*) that occur in beds of upper Barremian age in the Sierrita del Chivo of northwestern Zacatecas. At Cumbre, about 5 miles northeast of Huizachal, have been found ammonites that W. S. Adkins[198] says are of Vraconnian (upper Albian) age, but he lists no genera to substantiate his statement. Near La Mula, a few miles west of Huizachal, was found an ammonite, *Pseudohaploceras*,[199] which indicates either Barremian or Aptian age. Immediately north of Aramberri, Nuevo León, Burckhardt[200] found some dwarfed, uncoiled ammonites that he considered Albian or Cenomanian in age.

The Upper Cretaceous has been identified in the broad synclinal valleys of southwestern Tamaulipas, Turonian limestone containing *Inoceramus labiatus* (Schlotheim) has been identified at Tamatán, several miles west-southwest of Victoria, and near La Mula, about 12 miles southwest of Victoria. Heim[201] notes that at the entrance of Cañón del Novillo, 5 kilometers southwest of Victoria, the Tamaulipas limestone is overlain by 5 meters of limestone questionably assigned to the Agua Nueva (Xilitla) formation, which in turn is overlain by 5 meters of San Felipe limestone. On the contrary, C. L. Baker[202] notes that at the mouth of Cañón del Novillo the Agua Nueva formation is normally developed, contains *Inoceramus labiatus* (Schlotheim), and has a basal limestone conglomerate. Heim says that west of Huizachal the Agua Nueva formation is lacking, or is represented by coarse limestone conglomerate and calcareous sandstone that grade into the San Felipe formation. Near Victoria the San Felipe formation ranges in thickness from 100 to 200 meters (328 to 656 feet) but thins west of

195 R. W. Imlay, *op. cit.* (1937b), pp. 554–59.

196 Carlos Burckhardt, *op. cit.* (1930), p. 154.

197 *Ibid.*, p. 155.

198 Arnold Heim, "The Front Ranges of Sierra Madre Oriental, Mexico, from Ciudad Victoria to Tamazunchale," *Eclogae geol. Helvetiae*, Vol. 33, No. 2 (1940), p. 321.

199 Carlos Burckhardt, *op. cit.* (1930), p. 155.

200 *Ibid.*, p. 171.

201 Arnold Heim, *op. cit.* (1940), p. 322.

202 John M. Muir, *op. cit.* (1936), p. 48.

Huizachal to only 50 meters (164 feet). It thickens southward and passes into the Tamasopo limestone near El Capulín, in southwestern Tamaulipas. It is overlain gradationally by the Méndez shale in the Victoria and Jaumave valleys.[203] Near Tula the Tamasopo limestone is overlain by about 300 meters of shales and sandy shales, assigned to the Méndez shale,[204] whose basal beds have furnished fossils identified by Adkins[205] as *Inoceramus barabini* Morton and *I. vanuxemi* Meek and Hayden. The latter indicates upper Campanian to lower Maestrichtian age.[206] Above the Méndez shale follow sandy shales, sandy limestone and sandstone containing many specimens of *Exogyra costata* Say and *Gryphaea vesicularis* Lamarck. These highest sandy beds represent a northern extension of the Cárdenas formation[207] of eastern San Luis Potosí, and are correlated with the Navarro formation of Texas.

SIERRA DE TAMAULIPAS IN SOUTHEASTERN TAMAULIPAS

The Tamaulipas limestone in the Sierra de Tamaulipas (Fig. 14) ranges from about 450 to 770 feet in thickness and comprises three lithologic units. The lowest unit consists of about 50 feet of black, thin-bedded limestone and shale that Muir[208] named the Otates beds. It contains a basal Albian fauna. The middle unit consists of 305 to 350 feet of white to light gray, mostly thick-bedded limestone containing many light to dark chert nodules. It has furnished fossils of middle Albian age but may be partly lower and upper Albian in age. The highest unit consists of 138 to 420 feet of gray, wavy-bedded, thin-bedded limestone containing many nodules and some lenses of black chert. It has not furnished fossils but must be partly of Cenomanian age as it grades upward into the Agua Nueva formation of Turonian age.[209] It is probably mainly upper Albian in age, as supposed by Böse and Cavins.[210]

The Otates beds in Cañón de Otates, which branches from the east end of Cañón de la Borrega on the western side of the Sierra Tamaulipas, have furnished ammonites identified by Burckhardt[211] as *Puzosia* sp. and *Parahoplites* of the group of *P. milletianus* (D'Orbigny) (equals *Hypacanthoplites* Spath). The

[203] Arnold Heim, *op. cit.* (1940), p. 324.

[204] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), pp. 76, 77.
Carlos Burckhardt, "Étude synthétique sur le mésozoïque mexicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 234.

[205] John M. Muir, *Geology of the Tampico Region, Mexico*, Amer. Assoc. Petrol. Geol. (1936), pp. 72, 73.

[206] L. W. Stephenson and J. B. Reeside, Jr., "Comparison of Upper Cretaceous Deposits of Gulf Region and Western Interior," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22 (1938), p. 1637.

[207] Arnold Heim, *op. cit.* (1940), p. 332.

[208] John M. Muir, *op. cit.* (1936), p. 28.

[209] *Ibid.*, pp. 25–32.

[210] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), p. 65.

[211] John M. Muir, *op. cit.* (1936), p. 27.

Otates beds in Cañón de los Perales (not Panales) have furnished *Puzosia* cf. *P. kiliani* Fallot, *Columbiceras* aff. *C. crassicostatus* (D'Orbigny), *Uhligella* sp., and *Inoceramus* cf. *I. anglicus* Woods.[212] These genera might indicate either upper Aptian or lower Albian age for the Otates beds, but the absence of *Dufrenoya*, which is highly characteristic of the upper Aptian of Mexico, favors lower Albian age. From the white to light gray, thick-bedded limestone above the Otates beds in Cañón de los Perales was obtained[212] *Lyelliceras prorsocurvatum* (Gerhardt);[213,214] which genus, according to Spath,[215] is restricted in Europe to the upper part of the lower Albian and the lower part of the middle Albian. Near El Pinto at the eastern end of Cañón de la Borrega the white limestones have furnished *Oxytropidoceras acutocarinatum* (Shumard),[216] a definite middle Albian marker. From an undesignated locality in the Tamaulipas limestone W. S. Adkins[217] records *Alectryonia carinata* Lamarck, *Inoceramus* cf. *I. concentricus* Parkinson, *I. comancheanus* Cragin, and *Idiohamites comanchensis* (Adkins and Winton). The last two species characterize the Texas Duck Creek formation, of basal upper Albian age.

The Agua Nueva formation in the Sierra de Tamaulipas[218] consists of 415 to 575 feet of dark, platy, laminated, medium- to thin-bedded limestone interbedded with black shale and containing some concretions of black chert. Its middle and upper parts contain many specimens of *Inoceramus labiatus* Schlotheim and *I. hercynicus* Petrascheck,[219] which are evidence of Turonian age. Its basal part contains an abundance of fish scales and bones and has been referred to the upper Cenomanian.[220]

The San Felipe formation, called the Solís limestone by Böse and Cavins,[221] grades downward into the Agua Nueva formation and upward into the Méndez shale. It consists of about 575 to 700 feet of light gray to cream-colored, mostly thin-bedded limestone, with shale partings that become more common near the top. Locally, it contains lenses of light gray chert and layers of bentonite. Some limestone beds in the lower part of the formation are of a characteristic greenish gray color. The main fossils are gigantic Inocerami, as much as 2 feet in width,

[212] Emil Böse and O. A. Cavins, *op. cit.* (1927), p. 64. Thanks are due S. A. Grogan, Paul Weaver' and Otto van Rossum for correcting the spelling of Perales.

[213] K. Gerhardt, Beitrag zur Kenntniss der Kreideformation in Columbien," *Neues Jahrb. Beilage-Band 11* (1897), p. 168, Pl. 4, Figs. 8a, b.

[214] L. Riedel, "Ammonites del cretácico inferior de la Cordillera Oriental," in "Estudios geológicos y paleontológicos sobre la Cordillera Oriental de Colombia," Pt. 2, *Rep. Colombia Dept. Minas y Petróleos* (1938), p. 53, Pl. 9, Figs. 3, 4.

[215] L. F. Spath, "Ammonoidea of the Gault," Pt. 8, *Paleontogr. Soc.*, Vol. 83 (1931), p. 15.

[216] John M. Muir, *op. cit.*, (1936), p. 27.

[217] John W. Muir, *op. cit.* (1936), p. 32.

[218] John M. Muir, *op. cit.* (1936), pp. 44, 45.

[219] Emil Böse and O. A. Cavins, *op. cit.* (1927), p. 67.

[220] John M. Muir, *op. cit.* (1936), p. 53.

[221] Emil Böse and O. A. Cavins, *op. cit.* (1927), p. 70.

and small oysters resembling *Ostrea congesta* Conrad. Stephenson[222] lists *Inoceramus* cf. *I. deformis* Meek and *Ostrea congesta* Conrad (?) from 10 kilometers west of Soledad just east of the crest of the Sierra de Tamaulipas. He found similar forms near Santa Isabel, on the west flank of the range about 21 kilometers east of Forlón Station. On the basis of these fossils, he correlated the San Felipe formation with the Austin chalk of Texas.

The Méndez shale cropping out on the flanks of the Sierra de Tamaulipas[223] attains a thickness of 935 feet in Cañón de la Borrega and Arroyo Membral east of Forlón station and consists mainly of light gray, hard, generally distinctly bedded shale. In many places it contains hard chalky or marly layers that are fairly resistant to weathering. The upper part of the formation contains a few meters of brownish red shale. The contact with the overlying Tamesí is an irregular surface of erosion. Correlation of the Méndez formation with the Taylor and Navarro in Texas is based mainly on fossils found in the Tampico area.

The Tamesí formation, of Tertiary age, exposed in Arroyo Membral,[224] consists of gray shale alternating with sandstone. The basal bed contains inclusions of the Méndez shale and is overlain by 1 to 4 feet of sandstone. Thicknesses have not been recorded.

SIERRA DE SAN CARLOS OF NORTHERN TAMAULIPAS

The Mesozoic section in the Sierra de San Carlos (Fig. 11) is very similar to that in the Sierra de Tamaulipas but apparently includes beds as old as the Neocomian and Upper Jurassic.[225] The Tamaulipas limestone comprises two members. The lower member consists of 2,000 to 3,000 feet of gray, thick-bedded limestone that locally contains chert nodules. The upper member consists of about 100 feet of gray, wavy-bedded, thin-bedded limestone that contains much black chert as nodules and lenses. The contact between these members is sharp but apparently conformable. From the lower member have been recorded fossils of upper Portlandian, Berriasian, and lower and middle Albian ages. W. H. Hegwein[226] found specimens of the upper Portlandian ammonite *Kossmatia* on Loma Rinconada in

[222] L. W. Stephenson, "Some Upper Cretaceous Shells of the Rudistid Group from Tamaulipas, Mexico," *Proc. U. S. Nat. Mus.*, Vol. 16, Art. 1 (1922), pp. 2, 3.

[223] John M. Muir, *op. cit.* (1936), pp. 25, 70.

[224] *Ibid.*, pp. 83, 84.

[225] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), pp. 60–67, 74, 75, 100, 136–42.
Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 153, 157, 166, 172, 221, 243, 266.
John M. Muir, *Geology of the Tampico Region, Mexico*, Amer. Assoc. Petrol. Geol. (1936), pp. 21, 22, 55, 56.
L. B. Kellum, "Geology of the Sedimentary Rocks of the San Carlos Mountains," *Univ. Michigan Sci. Ser.*, Vol. 12 (1937), pp. 38–53, 68–92.
R. W. Imlay, "Geology of the Sierra de Cruillas, Tamaulipas, Mexico," *Univ. Michigan Sci. Ser.*, Vol. 12 (1937d), pp. 217–221.

[226] Carlos Burckhardt, *op. cit.* (1930), p. 266.
L. B. Kellum, *op. cit.* (1937), pp. 39, 40, 45.

the Sierra de Cruillas and a specimen of the typically Berriasian genus *Neocosmoceras* in the northeastern part of the main range of the Sierra de San Carlos. The occurrence of a Jurassic fossil in the Sierra Cruillas is significant, because in that range the outcrops of the lower member of the Tamaulipas limestone are only about 700 feet thick. Consequently, the main mass of the Tamaulipas limestone elsewhere in the Sierra de San Carlos may be of Jurassic age. If this is true, the Lower Cretaceous is much thinner than in the Sierra Madre Oriental or in the Tampico area, and the late Upper Jurassic (Kimmeridgian to Tithonian) sequence is thinner and more calcareous than in those areas. The implications of Hegwein's discovery are so significant from the viewpoint of petroleum exploration that the occurrence of Jurassic fossils should be verified by additional field work. At least no doubt exists as to the upper Aptian to middle Albian age of the upper few hundred feet of the lower member of the Tamaulipas limestone, as Böse, Cavins, Kellum, and Imlay obtained fossils at many localities, and the evidence has been thoroughly discussed by Kellum.[227]

Fossils of probable upper Aptian age have been found (1) on Loma Palmar in the Sierra Cruillas, (2) in Cañón Tamaulipeca in the western part of the Sierra de San Carlos, and (3) at Hegwein's locality 78 in the northeastern part of the Sierra de San Carlos.[228] Collections from these localities are characterized by the presence of *Pseudohaploceras* [equals *Puzosia* of the group of *P. liptoviensis* (Zeuschner)], which ranges through Barremian and Aptian but is not known from the Albian. In addition, the collection from Cañón Tamaulipeca contains *Beudanticeras*, a genus not known below the upper Aptian, and the collection from Loma Palmar contains a species of *Acanthoplites* comparable with *A. multispinatus* (Anthula) from the Aptian of the Caucasus.

Lower Albian fossils, reported by Böse and Cavins[229] from two localities in Cañón de San Nicolas, include such forms as *Puzosia*, *Uhligella*, *Hypacanthoplites*, *Acanthoplites*, *Parahoplites*, and *Inoceramus* cf. *I. anglicus* Woods. Many of the species have been identified, or compared, with European lower Albian species. They occur in yellowish to reddish to gray, thin-bedded limestone.

Fossils of middle Albian age have been found at seven localities in the Sierra de San Carlos, and at one locality in the Sierra de Cruillas.[230] They include such forms as *Beudanticeras*, *Latidorsella*, *Puzosia*, *Uhligella*, *Engonoceras*, *Oxytropidoceras*, *Inoceramus* aff. *I. concentricus* Parkinson, and *I. subsulcatiformis* Böse. Particularly significant is the occurrence of middle Albian fossils only 20 feet below the top of the lower member in Cañón Guijano about one mile northeast of El Milagro in the Sierra de Cruillas. The upper member of the Tamaulipas limestone has not furnished fossils, but its stratigraphic position shows that it must represent the upper Albian and part of the Cenomanian.

[227] L. B. Kellum, *op. cit.* (1937), pp. 47–50, 68–90.

[228] *Ibid.*, pp. 45, 46.

[229] Emil Böse and O. A. Cavins, *op. cit.* (1927), p. 60.

[230] L. B. Kellum, *op. cit.* (1937), pp. 45–47.

In the Sierra de San Carlos the Agua Nueva formation was included in the basal part of the San Felipe formation by Kellum[231] and Imlay[232] but was considered a distinct lithologic unit by Böse and Cavins[233] and by L. G. Putnam.[234] The Agua Nueva formation is characterized by dark, platy, medium- to thin-bedded limestone containing some interbedded dark shale and a little chert. It grades downward into the Tamaulipas limestone within a few feet but is easily distinguished by its thinner bedding and its buff weathering. It grades upward into the San Felipe within 10 feet but is recognized by its darker color on fresh surfaces, platy bedding, and regular fracturing. Its thickness is probably not much more than 300 feet. A Turonian age is shown by the occurrence of *Inoceramus hercynicus* Petrascheck near El Palmar, at the upper end of Cañón de San Nicolas.[235]

The San Felipe formation consists of light to dark yellowish gray, medium- to thin-bedded, chalky limestone containing many shale partings that become more common upward. Its upper 50 to 55 feet are transitional into the Méndez shale. Its measured thickness in the north-central part of the range is 550 feet.[236]

The Méndez shale studied north of the mountains near El Mulato consists of about 2,850 feet of medium to dark gray, calcareous, nodular to fissile shale containing abundant Foraminifera. The contact with the overlying Tamesí formation is apparently conformable according to Kellum,[237] but Putnam[238] observed that the thin basal sandstone of the Tamesí formation contains limestone conglomerate and locally shale fragments derived from the Méndez shale.

The Tamesí formation, of early Tertiary age, near El Mulato consists of dark gray shale above 4 to 15 feet of basal sandstone and is about 1,320 feet thick. Muir[239] notes that it is overlain by beds of Midway age but fails to describe the contact or cite fossil evidence for the presence of Midway beds.

GALEANA-MONTEMORELOS-LINARES AREA OF SOUTH-CENTRAL NUEVO LEÓN

No detailed studies have been made in this area. At Galeana the lower part of the Lower Cretaceous sequence, from top to bottom,[240] is as follows.

[231] L. B. Kellum, *op. cit.* (1937), pp. 50, 51, 53.

[232] R. W. Imlay, *op. cit.* (1937d), pp. 218, 220, 221.

[233] Emil Böse and O. A. Cavins, *op. cit.* (1927), pp. 66–68.

[234] John M. Muir, *op. cit.* (1936), p. 56.

[235] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), p. 67.

[236] L. B. Kellum, *op. cit.* (1937), pp. 50, 53.
John M. Muir, *op. cit.* (1936), p. 56.

[237] L. B. Kellum, *op. cit.* (1937), pp. 51–53.

[238] John M. Muir, *op. cit.* (1936), p. 85.

[239] John M. Muir, *op. cit.* (1936), pp. 85, 92.

[240] Emil Böse and O. A. Cavins, *op. cit.* (1927), pp. 57, 58.
Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 154.

4. Limestone, thin-bedded, with interbedded gray marl and shale
3. Shale, sandy, gray, interbedded with sandstone and limestone; contains many *Olcostephanus* group of *O. astieri* (D'Orbigny)
2. Sandstone, coarse, and conglomerate, red and gray
1. Limestone, medium- to thin-bedded, gray to black, with intercalations of gray marl; weathers whitish to yellowish; contains *Neocomites*, *Acanthodiscus* cf. *A. ottmeri* Neumayr and Uhlig, *Thurmannites* sp., and *Crioceras* sp.; overlies upper Jurassic beds

Burckhardt and Böse assigned units 1 to 3 to the Valanginian, but the presence of an *Acanthodiscus* comparable with *A. ottmeri* is good evidence of lower Hauterivian age for at least part of the basal unit. No fossil evidence for the existence of the Berriasian, Barremian, or Aptian has been reported. Böse and Cavins[241] state that the lower and middle Albian along the easternmost front of the Sierra Madre Oriental from Lampazos to Victoria consist of dark, medium- to thick-bedded limestone containing highly ornamented ammonites, and that this facies passes westward within a short distance into a rudistid facies. The latter is commonly called the Aurora limestone and is restricted to a rather narrow zone along the Sierra Madre Oriental. The upper Albian and probably part of the Cenomanian are represented by thin-bedded limestone containing lenses and nodules of black chert, as in the Sierra de San Carlos. The Turonian[242] cropping out east of the mountain front ranges from 250 to 350 meters in thickness and consists mainly of dark shale. It has furnished *Inoceramus hercynicus* Petrascheck at Los Ahorcados south of Montemorelos and in Cañón de Santa Rosa west of Linares. The Turonian is overlain by a thick mass of gray shale that was named the Papagayos shale by Dumble[243] but is now generally called Méndez shale. Near Linares the lower part of the Méndez (Papagayos) shale contains some marl and thin limestone beds which weather into elliptical nodules and furnish *Inoceramus* group of *I. balticus* Böhm that, according to Böse and Cavins[244] may be identical with a species in the Austin chalk. The upper part of the Méndez shale[245] differs from the lower part in being darker and weathering into splintery pieces. It is overlain near Linares and farther east by thick-bedded non-marine sandstone that Böse and Cavins[246] considered late Cretaceous but that forms the basal beds of the Tamesí formation, of early Tertiary age.

MONTERREY-CIÉNEGA EL TORO-SALTILLO AREA

The best described section of Lower Cretaceous in the mountains between and south of Monterrey and Saltillo (Figs. 9, 11, 13) is in Cañón de los Cortinas, which

[241] Emil Böse and O. A. Cavins, *op. cit.* (1927), pp. 59, 86, 87.

[242] *Ibid.*, p. 67.

[243] E. T. Dumble, "Tertiary Deposits of Northeastern Mexico," *Science*, New Ser., Vol. 33 (1911), p. 233.

[244] Emil Böse and O. A. Cavins, *op. cit.* (1927), p. 69.

[245] *Ibid.*, p. 72.

[246] *Ibid.*, p. 74.

drains northward across the Sierra de Los Muertos south of Casa Blanca on the Monterrey to Saltillo highway. The section from top to bottom[247] follows.

	Thickness in Feet
Cuesta del Cura limestone	
Limestone, thin-bedded, wavy-bedded, contains lenses and nodules of black chert	300–400
Aurora limestone	
Limestone, medium- to thick-bedded, dark gray, contains some dark gray to black chert nodules and poorly preserved rudistids	2,000+
La Pena formation	
Shale and marly, thin-bedded limestone, gray, weathers reddish gray. Upper half contains *Dufrenoya* and other ammonites of upper Aptian. Highest fossiliferous beds may be basal Albian in age	100–150
Cupido limestone	
Limestone, partly dolomitic, upper three-fourths medium- to thick-bedded, lower one-fourth medium- to thin-bedded, base marked by 150 to 175 feet of dark gray to black, thick-bedded dolomitic limestone that is underlain by 35 to 40 feet of medium-bedded limestone	2,600
Las Cortinas formation (as defined by Humphrey)	
Shale, calcareous, and thin lenses of marly limestone, gray, weathers light gray to yellowish	700
Limestone, shaly, and calcareous shale, gray, weathers dark gray to brown. Contains *Thurmannites* and *Neocomites*	175
Limestone, thick-bedded, dark to medium gray, contains many corals and bryozoans	100–120
Shale and limestone interbedded, dark gray, contains many oyster remains, rests on coarse clastic sediments of lower Portlandian age	170(?)

The Las Cortinas formation as defined by Humphrey includes beds ranging in age from upper Neocomian to upper Portlandian. It seems most likely that the 100 to 120 feet of thick-bedded, coralline limestone marks the base of the Cretaceous because (1) similar limestone occurs at the base of the Cretaceous at many places in Coahuila, Zacatecas, and Nuevo León;[248] (2) coralline beds occur in beds of Neocomian age in northern Mexico[249] but have not been reported from beds of Kimmeridgian to Tithonian age; and (3) the thickness of the upper Portlandian-Tithonian beds in the Monterrey-Ciénega El Toro-Saltillo area only ranges from 20 to 50 meters (65 to 165 feet) according to Böse,[250] and is generally less than 130 feet in southern Coahuila and northern Zacatecas.[251] The Cretaceous part of Las Cortinas formation is so similar lithologically to the Taraises formation that introduction of a new name does not seem justified.

[247] Wm. E. Humphrey, "Stratigraphy of Cortinas Canyon Section, Sierra de los Muertos, Coahuila, Mexico," *South Texas Geol. Soc. 13th Ann. Meeting, Guide Book* (1941), pp. 3, 4, and structure section.

[248] Emil Böse and O. A. Cavins, *op. cit.* (1927), p. 18.
R. W. Imlay, "Ammonites of the Taraises Formation of Northern Mexico," *Bull. Geol. Soc. America*, Vol. 49 (1938a), pp. 542–45.

[249] R. W. Imlay, "Neocomian Faunas of Northern Mexico," *Bull. Geol. Soc. America*, Vol. 51 (1940a), p. 129.

[250] Emil Böse, "Vestiges of an Ancient Continent in Northeast Mexico," *Amer. Jour. Sci.*, 5th Ser., Vol. 6 (1923b), pp. 207, 209.

[251] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 58, 59.
R. W. Imlay, "Upper Jurassic Ammonites from Mexico," *Bull. Geol. Soc. America*, Vol. 50 (1939a), pp. 8, 11.

Many fossils of Valanginian and Hauterivian ages have been reported from the Taraises formation of this area.[252] In the Sierra Borrada near San Rafael, Nuevo León, the basal beds consist of thin-bedded limestone with intercalations of shale and contain *Thurmannites* cf. *T. thurmanni* (Pictet and Campiche). The upper beds consist of yellowish shales and marls containing many *Olcostephanus*. In the Hacienda de las Vacas, Coahuila, the basal beds consist of thin-bedded limestone interbedded with shale and the higher beds of siliceous, medium-bedded limestone. Both contain *Olcostephanus* cf. *O. astieri* (D'Orbigny) and *Neocomites* cf. *N. neocomiensis* (D'Orbigny). In the Sierra de la Marta near Santa Clara, Nuevo León, the basal limestones are overlain by shale alternating with thin limestone containing *Thurmannites* and *Olcostephanus*. In the Sierra de Huachichil, Coahuila, the basal medium-bedded limestones contain paleohoplitids, and the overlying interbedded shale and limestone contain *Olcostephanus*. In Cañón Agua del Pocito south of Sierra de las Pintas near Ciénega del Toro, Nuevo León, occur dark limestone and marl containing many *Olcostephanus* and *Leopoldia*[252a]. A Federal Geological Survey collection made by W. R. Smith from the mountains west of Monterrey contains *Thurmannites*, *Leopoldia*, *Olcostephanus*?, and *Acanthodiscus* cf. *A. magnificus* Imlay. The collections containing *Leopoldia* are definitely of lower Hauterivian age. Böse and Cavins[253] supposed the basal thick- to thin-bedded limestones were of Berriasian age, and that the overlying shale and marl containing *Olcostephanus*, *Neocomites*, and *Thurmannites* were mainly of Valanginian age. However, the writer[254] has shown that in southern Coahuila, northern Zacatecas, and eastern Durango the basal, thick- to thin-bedded limestones are of Valanginian age, or locally of Berriasian and Valanginian age, and that the overlying marls and thin-bedded limestones are of lower Hauterivian age.

The Cupido limestone has furnished few fossils, except fragmentary rudistids at its top, but its stratigraphic position indicates a Barremian and lower Aptian age. The overlying La Peña formation contains a large fauna of upper Aptian age,[255] including the genera *Dufrenoya*, *Parahoplites*, *Columbiceras*, *Uhligella*, *Puzosia*, and *Cheloniceras*. The highest beds of the La Peña formation may be of basal Albian age, as Burckhardt[256] records *Parahoplites* cf. *P. multicostatus* Sinzow from the Bufa de Cabrillas south of Los Muertos, Coahuila.

The Aurora limestone between Monterrey and Saltillo contains poorly pre-

[252] Emil Böse, *op. cit.* (1923b), pp. 202, 207, 209–11.
Carlos Burckhardt, *op. cit.* (1930), pp. 86, 142.

[252a] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), p. 58.

[253] Emil Böse and O. A. Cavins, *op. cit.* (1927), p. 18.

[254] R. W. Imlay, "Ammonites of the Taraises Formation of Northern Mexico," *Bull. Geol. Soc. America*, Vol. 49 (1938a), pp. 550–52.

[255] Emil Böse, *op. cit.* (1923b), pp. 211, 212.
Emil Böse and O. A. Cavins, *op. cit.* (1927), pp. 19, 20.

[256] Carlos Burckhardt, *op. cit.* (1930), p. 143.

served rudistids, and its determination as lower and middle Albian in age is based on stratigraphic position. The overlying Cuesta del Cura limestone, according to Böse,[257] is about 100 meters (328 feet) thick and contains many small ammonites, including *Mortoniceras* (*Pervinquieria*) and uncoiled forms.

The overlying Upper Cretaceous section exposed in the area north and west of Saltillo has never been studied in detail. Humphrey[258] notes that in the Cañón de los Muertos northeast of Saltillo is exposed a sequence from the Cuesta del Cura limestone to nearly the top of the Upper Cretaceous, including equivalents of the Indidura formation, Parras shale, and Difunta formation. The combined thickness of these Upper Cretaceous beds probably exceeds 18,000 feet. According to Böse[259] the Cenomanian is represented by unfossiliferous gray shales alternating with thin-bedded limestones, generally has a reddish or yellowish, fine-grained sandstone at the base, and is not less than 300 meters (985 feet) thick. It grades up into fossiliferous beds of Turonian age[260] composed of dark gray to black, thinly laminated, thin-bedded limestone alternating with dark shale and having a thickness of 300 to 400 meters (985 to 1,310 feet). Böse reports *Inoceramus labiatus* (Schlotheim) and *I. hercynicus* Petrascheck from these beds at the foot of the mountains between Saltillo and Ramos Arizpe. *Inoceramus labiatus* (Schlotheim) was likewise found at San Juan Bautiste, Nuevo León, and at Mesa de Tablas, Coahuila. The Turonian beds are overlain by dark shale, probably several thousand feet thick, comparable lithologically and stratigraphically with the Parras shale farther west. The overlying late Upper Cretaceous beds are well exposed in the mesa northeast, north, and west of Saltillo. They consist of an enormous thickness of gray to brown sandstone, shale, marl, and limestone in which the sandstone becomes more common near the top and contain the zones of *Exogyra ponderosa* Roemer and *E. costata* Say. It is reported that on the Mesa de Guajardo west of Saltillo, the beds containing *Exogyra ponderosa* and *E. costata* are at least 6,000 feet thick, but details of the section have not been published. These beds are overlain by at least 6,000 feet of green, red, and brown sandstones and shale without marine invertebrates, but with large reptilian remains, according to Wm. E. Humphrey.[261]

MAZAPIL-CONCEPCIÓN DEL ORO-MELCHOR OCAMPO AREA OF NORTHERN ZACATECAS

The geologic features of the mountains near Mazapil, Concepción del Oro, and Melchor Ocampo (formerly San Pedro Ocampo) in northeastern Zacatecas

[257] Emil Böse, "Vestiges of an Ancient Continent in Northeast Mexico," *Amer. Jour. Sci.*, 5th Ser., Vol. 6 (1923b), pp. 212, 213.

[258] Wm. E. Humphrey, "Stratigraphy of Cortinas Canyon Section, Sierra de los Muertos, Coahuila, Mexico," *South Texas Geol. Soc. 13th Ann. Meeting, Guide Book* (1941), p. 1.

[259] Emil Böse, *op. cit.* (1923b), p. 213.

[260] Emil Böse, *op. cit.* (1923b), p. 214.

[261] Personal communication.

(Fig. 10) have been described in fair detail.[262] The most complete section of the Cretaceous is exposed on the Sierra Sombreretillo and along its southern base immediately north of Melchor Ocampo[263] and from top to bottom may be described as follows:

	Thickness in Feet
Parras shale	
Dark calcareous shale containing some thin beds of tuff in lower 600 feet	2,000±
Caracol formation	
Shale mainly, some interbedded tuff	536
Tuff and some shale. Tuff, gray, friable, fairly coarse-grained; weathers yellowish gray	180
Shale, dark gray, predominant, but containing many thin beds of yellowish brown tuff; some tuff beds as thick as 6 inches; several lenses of deep yellow limestone about 180 feet from top	1,090
Shale and tuff interbedded in about equal amounts; tuff rather coarse-grained	182
Shale, dark gray and yellowish gray, but containing considerable yellowish brown tuff which weathers deep red	425
Shale, dark gray and yellowish gray; contains many thin beds of yellowish brown and brownish black tuff which weather respectively brownish red and yellowish; some tuff beds as thick as 3 inches	825
Shale, dark gray; contains some beds of red and brownish black tuff; a few lenses of deep yellow limestone in lower 70 feet	112
Indidura formation	
Limestone, thin-bedded, platy and shaly, light gray to yellowish gray; becomes shalier toward top	560
Cuesta del Cura limestone	
Limestone, thin-bedded, wavy-bedded, dark gray to brownish black; contains many thin lenses and bands of black chert	580
Limestone, medium- to thin-bedded, medium to dark gray; contains nodules and lenses of black chert; becomes thicker bedded in lower 50 feet. Thin-bedded limestones are less wavy-bedded than in overlying member	250
La Pena formation	
Limestone, thin-bedded and platy, with shaly partings, yellowish gray; interbedded with many thin beds of black chert; becomes thicker bedded toward base	160
Limestone, thin- to medium-bedded, yellowish gray, interbedded with lenses of black chert	100
Cupido limestone	
Limestone, thick- to medium-bedded, medium gray; some beds pinkish or yellowish gray; some yellowish brown chert nodules	193
Limestone, thick-bedded, light gray	307
Limestone, medium- to thin-bedded, light gray	362
Taraises formation	
Limestone, thin-bedded and marly, light gray; some beds pinkish gray; weathers light yellowish gray; some thin beds of black chert near base	215
Limestone, thick-bedded, light to medium gray	248
Total thickness	8,325

The Taraises formation rests conformably on Upper Jurassic shaly limestone, ranges in thickness from 463 feet on Sierra Sombreretillo to 330 feet near Mazapil,

[262] Carlos Burckhardt, "Géologie de la Sierra de Concepción del Oro," *International Geol. Congress X, Mexico, Guide Excursion 24* (1906a), map, 24 pages. "Géologie de la Sierra de Mazapil et Santa Rosa," *International Geol. Congress X, Mexico, Guide Excursion 26* (1906b), maps, 40 pages. "La faune jurassique de Mazapil avec un appendice sur les fossiles du crétacique inférieur," *Bol. Inst. Geol. México*, Núm. 23 (1906c), 43 plates, 216 pages. "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 125–27, 131–34, 166–70, 220, 240.

R. W. Imlay, "Studies of the Mexican Geosyncline," *Bull. Geol. Soc. America*, Vol. 49 (1938b), pp. 1651–94.

[263] R. W. Imlay, *op. cit.* (1938b), pp. 1662–67.

and consists of a lower member of compact, thick- to medium-bedded limestone and an upper member of thin-bedded to marly limestone. The lower member has not furnished fossils. The upper member has furnished species of *Olcostephanus*, *Dichotomites*, *Distoloceras*, *Neocomites*, and *Thurmannites*, which Burckhardt[264] considered of Valanginian age, but which the writer[265] determined to be of lower Hauterivian age. Fossils of this age have been recorded from (1) Cañón San Francisco in the Sierra Zuloaga, (2) two miles from the east end of the Sierra Zuloaga, (3) Sierra Canutillo west of Puerto Canutillo, (4) Vereda del Quemado and (5) Cuesta de los Colorines in the Sierra de la Caja, (6) Puerto Blanco and (7) Cañón de los Bocas in the Sierra de Santa Rosa.

The Cupido limestone consists of gray, thick- to medium-bedded limestone, is somewhat thicker-bedded than in the Sierra de Parras on the north, and ranges in thickness from 862 feet on Sierra Sombreretillo to 1,123 feet near Mazapil. Its age, on the basis of stratigraphic position, must range from upper Hauterivian, or Barremian, to lower Aptian. From the lower part of the formation on the south slope of the Sierra la Caja, north of Mazapil, have been recorded[266] *Holcodiscus* and *Pseudohaploceras*. The former is strictly a Barremian genus, and the latter ranges from Barremian to upper Aptian.

The La Peña formation of northeastern Zacatecas consists of thin-bedded to shaly limestone interbedded with many thin lenses of black chert, ranges in thickness from 250 to 400 feet, and is distinguished from the Cuesta del Cura limestone by absence of wavy bedding and by its platy character. It has furnished lower Albian species of *Hypacanthoplites*, *Columbiceras*, and *Acanthoplites* from Puerto Arrieros in the Sierra de Santa Rosa, southeast of Mazapil.[267] It may be mainly Aptian in age, as in southern Coahuila and eastern Durango,[268] although no Aptian fossils have been recorded.

The Cuesta del Cura limestone of northeastern Zacatecas consists mainly of dark gray, wavy-bedded, thin-bedded limestone interbedded with many lenses of black chert but basally contains units of medium-bedded limestone that are not wavy-bedded. It attains a thickness of 830 feet on Sierra Sombreretillo north of Melchor Ocampo and about 1,025 feet on Sierra de Santa Rosa south of Mazapil. Its age is mainly Albian but possibly includes some Cenomanian.[269] The middle Albian is indicated by *Oxytropidoceras* aff. *O. acutocarinatum* (Shumard), found on the western slope of the Sierra de Concepción del Oro on the road to Mazapil. The upper Albian is represented by *Hysteroceras aguilerae* (Böse),

[264] Carlos Burckhardt, *op. cit.* (1930), pp. 126, 127.

[265] R. W. Imlay, *op. cit.* (1938a), pp. 551, 552.

[266] Carlos Burckhardt, "Étude synthétique sur le mésozoïque mexicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 126.

[267] Carlos Burckhardt, "Faunas del aptiano de Nazas (Durango)," *Bol. Inst. Geol. México*, Núm. 45 (1925), p. 53.
———, *op. cit.* (1930), p. 134.

[268] R. W. Imlay, *op. cit.* (1938b), p. 1664.

[269] Carlos Burckhardt, *op. cit.* (1930), pp. 126, 168, 169.

Mortoniceras (*Pervinquieria*) sp., and *Turrilites* sp., found in the middle of the formation on the northeastern side of Sierra de Concepción del Oro. A number of uncoiled ammonites from the mountains near Mazapil and Concepción del Oro were con idered by Böse[270] as characteristic of the upper Albian.

The Indidura formation consists of shaly to platy, thin-bedded limestone and ranges in thickness from 560 feet near Melchor Ocampo to 635 feet near Mazapil. It is sharply differentiated from the underlying Cuesta del Cura formation, but the relationship appears to be conformable. The basal beds of the Indidura formation on the flanks of the Sierra de Santa Rosa south of Mazapil have furnished ammonites that Burckhardt[271] identifies as *Turrilites* of the group of *T. costatus* Lamarck and *Scaphites* and assigns to the Cenomanian. Most of the formation is of Turonian age, as Böse[272] records (1) *Inoceramus labiatus* (Schlotheim) from Cerro del Tanquecito on the Sierra de Concepción del Oro, and (2) *I. labiatus*, *Pachydiscus* cf. *P. flaccidicosta* Roemer (equals *Canadoceras?*), and *Acanthoceras* aff. *A. schlueterianum* Laube and Bruder (equals *Mammites?*) from Mina de Gallos Blancos in the Sierra de Santa Rosa.

The Caracol formation has been observed as far south as Mazapil, and the Parras shale as far south as Melchor Ocampo. Fossils were not found in them, and their age determinations are based on comparisons with the Parras section in southern Coahuila.

CAMACHO-OPAL AREA OF NORTHERN ZACATECAS

The section between Camacho and Opal in northwestern Zacatecas described by Böse[273] may be summarized from top to bottom as follows.

	Thickness in Feet
4. Sandstone, yellow, red, and green, alternating with gray, marly shale and some beds of gray limestone. Basal part contains *Inoceramus* aff. *I. cycloides* Wegner. Crops out on plain for many kilometers south of Opal and attains enormous thickness	?
3. Limestone, thin-bedded, dark gray to reddish gray, alternating with gray to black marl and shale. Contains *Inoceramus labiatus* (Schlotheim), *I. hercynicus* Petrascheck, *I. opalensis* Böse, and *I.* aff. *I. latus* Elbert. Outcrops west of Opal	328±
2. Limestone, thin-bedded, gray; a few lenses of black chert in lower part; contact gradational; no fossils	328±
1. Limestone, thin-bedded, gray to black, and many nodules, lenses, and beds of black chert. Contains large fauna of upper Albian age. Genus *Scaphites* occurs mainly in the upper beds and may indicate Cenomanian age for those beds. Exposed on small hill west of Opal. Base not known	164±

In this section unit 1 can be identified as the Cuesta del Cura limestone, units 2 and 3 as the Indidura formation, and unit 4 is suggestive of the Caracol forma-

[270] Emil Böse, "Algunas faunas cretácicas de Zacatecas, Durango y Guerrero," *Bol. Inst. Geol. México*, Núm. 42 (1923a), pp. 136–40, 161–64.
Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), p. 89.

[271] Carlos Burckhardt, *op. cit.* (1930), pp. 126, 169.

[272] Emil Böse, "Algunas faunas del cretácico superior de Coahuila y regiones limítrofes," *Bol. Inst. Geol. México*, Núm. 30 (1913), pp. 19, 20, 28.

[273] Emil Böse, *op. cit.* (1923a), pp. 30–46, 59–63, 68.
Carlos Burckhardt, *op. cit.* (1930), pp.128, 167–69, 220, 240.

tion but may include other formations. From unit 1 Böse[274] has obtained ammonites that he refers to *Lytoceras*, *Macroscaphites?*, *Hamites*, *Hamulina*, *Ptychoceras*, *Diptychoceras*, *Anisoceras*, *Turrilites*, *Baculites*, *Ancyloceras*, *Toxoceras*, *Crioceras*, *Acanthoceras*, *Desmoceras*, *Scaphites*, *Schloenbachia*, and *Brancoceras*. The forms from the Opal-Camacho area that Böse referred to *Brancoceras* and *Schloenbachia* belong to *Hysteroceras*, a characteristic upper Albian genus. The specimen referred to *Acanthoceras* aff. *A. lyelli* Leymerie (D'Orbigny) is probably a *Lyelliceras*, which genus, according to Spath[275] does not range above the lower part of the middle Albian in Europe. The species of *Scaphites* are much more apt to be of Cenomanian age than of upper Albian age. Although Böse attributed the entire fauna to the upper Albian, most of his specimens were obtained from isolated blocks scattered over the plain west of Camacho and may, therefore, represent several stratigraphic levels ranging from the middle Albian to the Cenomanian, as suggested by Burckhardt.[276]

SIERRAS RAMÍREZ AND DEL CHIVO OF SOUTHEASTERN DURANGO AND NORTHERN ZACATECAS

The Cretaceous rocks in the Sierras Ramírez and del Chivo have been described by Böse[277] and have been examined by the writer.[278] The section in the Sierrita del Chivo from top to bottom follows.

	Thickness in Feet
5. Limestone, thin-bedded, gray to brown, weathers brown to yellow; contains beds and lenses of dark chert; no fossils	98
4. Limestone, yellow to red, rarely gray, alternating with yellow or gray shale and marl; contains many species of *Pseudohaploceras*	66
3. Limestone, thick- to thin-bedded, gray, yellow, and reddish yellow, with nodules of red and brown chert; alternates with gray to yellow marl; contains *Pulchellia* and *Pseudohaploceras*	66
2. Limestone, medium- to thin-bedded and marly, grayish, yellowish, locally reddish; weathers light gray to yellowish gray; becomes more marly toward base; has nodules of limonite; contains many ammonites, including *Olcostephanus*, *Mexicanoceras*, *Neocomites*, *Thurmannites*, and *Distoloceras*	590
1. Limestone, compact, medium- to thin-bedded, gray to yellowish gray; weathers light gray; some marly partings; contains a few ammonites, including *Spiticeras*, *Kilianella*, *Valanginites*, and *Berriasella*	130
Total thickness	950

Units 1 and 2 belong to the Taraises formation. Units 3 and 4 greatly resemble the Parritas formation of the western part of the Sierra de Parras. Unit 1 must

[274] Emil Böse, *op. cit.* (1923a), p. 31.

[275] L. F. Spath, "Ammonoidea of the Gault," Pt. 8, *Paleontogr. Soc.*, Vol. 83 (1931), p. 315.

[276] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 167.

[277] Emil Böse, "Algunas faunas cretácicas de Zacatecas, Durango y Guerrero," *Bol. Inst. Geol. México*, Núm. 42 (1923a), pp. 19–29, 63–118.
Carlos Burckhardt, *op. cit.* (1930), pp. 127, 128, 131–34.

[278] R. W. Imlay, "Ammonites of the Taraises Formation of Northern Mexico," *Bull. Geol. Soc. America*, Vol. 49 (1938a), pp. 542, 550.

represent both the Berriasian and Valanginian, as *Spiticeras* is characteristic of the former and *Valanginites* of the latter. Unit 2 was assigned to the Valanginian by Böse[279] and Burckhardt,[280] but the writer[281] has presented ample evidence that it belongs to the Hauterivian. Unit 3 contains *Pulchellia*, a genus characteristic of the lower Barremian, although ranging down into the upper Hauterivian. The association of *Pulchellia* with *Pseudohaploceras* shows that the age is not older than Barremian. Unit 4 is probably upper Barremian, judging by its stratigraphic position, the abundance of *Pseudohaploceras*, and the absence of ammonites of definite Aptian age. Unit 5 can hardly be younger than basal Aptian.

MIDDLE PART OF SIERRA DE PARRAS, SOUTHERN COAHUILA

This area (Figs. 9 and 10) was first hastily examined by Böse[282] and later studied in fair detail by the writer.[283] The most complete Cretaceous section, exposed in the La Casita uplift and in the plain on the north, may be summarized from top to bottom as follows.

	Thickness in Feet
Difunta formation	
10. Sandstone, shale, and some limestone, gray to brown mainly; upper part contains *Sphenodiscus*	12,000+
Parras shale	
9. Shale, dark gray to black; lower part contains many thin beds of dark gray, fine-grained sandstone that become less common westward	4,000+
Caracol formation	
8. Shale, dark gray to greenish gray; many thin beds of tuff and limestone, and some novaculite; colors of tuff are white, yellow, gray, green, brown, and black; thins westward	990
Indidura formation	
7. Limestone, thin-bedded to shaly, interbedded with some shale, brown to brownish black; weathers light yellow; middle and upper parts contain *Inoceramus* cf. *I. labiatus* (Schlotheim); thickens southward to about 900 feet and westward to about 1,700 feet near Parras	170
Cuesta del Cura limestone	
6. Limestone, wavy-bedded, mostly thin-bedded, dark gray to brownish black; includes many lenticular layers of black chert; thickens southward to about 1,000 feet in southern part of Sierra de Parras	240
Aurora limestone	
5. Limestone, thick- to medium-bedded, light to dark gray; many beds contain rudistids or other pelecypods; other beds contain yellowish gray chert nodules; a few beds of gray dolomitic limestone and brown, sugary-grained dolomite; basal beds contain large specimens of *Exogyra quitmanensis* Cragin; thins markedly south of La Casita uplift to about 600 feet and consists of units of thick- to medium-bedded limestone alternating with units of thin-bedded limestone containing many thin layers of black chert	2,335
La Peña formation	
4. Limestone, gray; medium- or thick-bedded units alternate with fossiliferous thin-bedded units that form less than half of total thickness; highest unit consists of thin-bedded limestone about 80 feet thick; thickens slightly southward	1,000

[279] Emil Böse, *op. cit.* (1923a), p. 20.

[280] Carlos Burckhardt, *op. cit.* (1930), pp. 126–29.

[281] R. W. Imlay, *op. cit.* (1938a), pp. 551, 552.

[282] Emil Böse, *op. cit.* (1923b), pp. 329–32.
Carlos Burckhardt, *op. cit.* (1930), pp. 136, 141, 175.

[283] R. W. Imlay, "Geology of the Middle Part of the Sierra de Parras" *Bull. Geol. Soc. America*, Vol. 48 (1937a), pp. 587–630; 14 pls., 4 figs.

	Thickness in Feet
Cupido limestone	
3. Limestone, thick- to thin-bedded, mostly medium-bedded, mostly dark gray; pyrite concretions common; light gray chert concretions uncommon; thickens slightly southward	1,400
Taraises formation	
2. Limestone, thin-bedded to shaly, light to dark gray, weathers yellowish to cream-colored or pinkish in spots; contains many ammonites preserved mainly as pyrite	130
1. Limestone, medium- to thin-bedded, medium to dark gray, compact, brittle; weathers light gray; contains few ammonites; makes sharp contact with underlying shales of La Casita formation	100
Total thickness	22,365

The upper member of the Taraises formation in the middle part of the Sierra de Parras has furnished many ammonites of lower Hauterivian age,[284] including species of *Olcostephanus*, *Maderia*, *Mexicanoceras*, *Ceratotuberculus*, *Spitidiscus*, *Saynoceras*, *Acanthodiscus*, *Distoloceras*, *Neocomites*, *Leopoldia*, *Thurmannites*, *Kilianella*, *Bochianites*, and *Neolissoceras*. Most of these were found in the lower part of the upper member, but the highest beds of the member in the Sierra de San Angel, about 5 miles southwest of La Casita,[285] contain *Olcostephanus*, *Distoloceras*, *Bochianites*, *Thurmannites*, and *Hemihoplites?* that indicate an age not younger than lower Hauterivian. The lower member has not furnished ammonites older than the Valanginian. *Kilianella* and *Dichotomites?* were obtained from the upper part of the lower member in Cañón del Organo. *Olcostephanus* and *Neocomites?* were obtained from the basal part of the lower member in Cañón de la Casita[286] about 50 feet above some upper Kimmeridgian ammonites. Therefore, in the La Casita uplift the Berriasian, if not also some of the Jurassic, is missing. A few miles southeast in the Sierra de Astillero the Upper Jurassic sequence is probably complete.

Fossils have not been found in the Cupido limestone, but its stratigraphic position shows that it is upper Hauterivian and Barremian in age.

The La Peña formation contains many ammonites and a few echinoids, brachiopods, pelecypods, and gastropods, of which most are rather poorly preserved. The lower part of the formation in the Sierra de Parras is lower Aptian and perhaps upper Barremian in age as indicated by some ammonites found about 1,000 feet below the top in the subsidiary ranges of Sierra Astillero and Sierra Mesquite del Sur. The ammonites include *Saynoceras mexicanum* Imlay, *Parencyloceras*, *Ancyloceras?*, and *Hemicrioceras*.[287] The highest unit, ranging from about 80 feet along the northern side of the Sierra de Parras to about 300 feet along the south-

[284] R. W. Imlay, "Ammonites of the Taraises Formation of Northern Mexico," *Bull. Geol. Soc. America*, Vol. 49 (1938a), pp. 539–602; 15 pls., 4 figs.
———, "Neocomian Faunas of Northern Mexico," *Bull. Geol. Soc. America*, Vol. 51 (1940a), pp. 159–66.

[285] R. W. Imlay, "Geology of the Middle Part of the Sierra de Parras," *Bull. Geol. Soc. America*, Vol. 48 (1937a), p. 624.
———, *op. cit.*, (1938a), p. 551.

[286] R. W. Imlay, *op. cit.* (1938a), pp. 550, 551.

[287] R. W. Imlay, *op. cit.* (1937a), p. 611.
———, *op. cit.* (1940a), p. 135.

ern side, is generally highly fossiliferous. Along the northern side it has furnished only upper Aptian ammonites of the *Dufrenoya texana* zone. Along the southern side it has furnished ammonites that apparently represent both the upper Aptian and basal Albian.[288] As similar beds in eastern Durango contain both upper Aptian and basal Albian ammonites[289] and near Mazapil, Zacatecas, contain basal Albian ammonites,[290] it seems likely that the highest few feet of the La Peña formation in the Sierra de Parras is of basal Albian age. This point will be settled by studies now in progress.

The Aurora limestone contains poorly preserved rudistids of which the genus *Toucasia* is most common. Its age, on the basis of stratigraphic position, must be lower and middle Albian. The Cuesta del Cura limestone in the Sierra de Parras is probably mainly upper Albian in age, but its thickening southward coincident with thinning of the underlying Aurora limestone suggests that its lowest beds become older southward. The Indidura formation is mainly Turonian in age, as its middle and upper beds contain *Inoceramus* similar to *I. labiatus* (Schlotheim), but its lower beds are probably Cenomanian in age. The Caracol formation grades westward near Parras into the upper part of Indidura formation, which contains the Coniacian ammonite *Peroniceras*. The stratigraphic position of the Parras shale shows that it must be Santonian in age and equivalent to the upper part of the Austin chalk. Most of the Difunta formation is characterized by *Exogyra ponderosa* Roemer and other fossils[291] that furnished a correlation with the Taylor marl of Texas, but *Sphenodiscus* has been reported from several thousand feet below the top of the formation on Picacho de las Cebolletas, about 2½ miles north of General Cepeda.[292]

WESTERN PART OF SIERRA DE PARRAS AND PARRAS BASIN, SOUTHERN COAHUILA

This area (Fig. 9) has been studied by Bernius,[293] Böse,[294] and the writer.[295] The Cretaceous sections exposed along Cañón Taraises, along the northern front

[288] R. W. Imlay, *op. cit.* (1937a), p. 610.
———, *op. cit.* (1938b), p. 1664.

[289] Carlos Burckhardt, "Faunas del Aptiano de Nazas (Durango)," *Bol. Inst. Geol. México*, Núm. 45 (1925), pp. 49–53.

[290] Carlos Burckhardt, "La faune jurassique de Mazapil avec un appendice sur les fossiles du crétacique inférieur," *Bol. Inst. Geol. México*, Núm. 23 (1906c), pp. 197, 198.
———, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 134.

[291] R. W. Imlay, "Stratigraphy and Paleontology of the Upper Cretaceous Beds along the Eastern Side of Laguna de Mayran, Coahuila, Mexico," *Bull. Geol. Soc. America*, Vol. 48 (1937c), pp. 1805–08.

[292] Personal communication from Wm. E. Humphrey.

[293] Karl Bernius, *Das Becken von Parras*. Dietrich Reimer, Berlin (1905).

[294] Emil Böse, "Excursion dans les environs de Parras," *International Geol. Congress X, Mexico, Guide Excursion 23* (1906c), 16 pp., map.

[295] R. W. Imlay, "Geology of the Western Part of the Sierra de Parras," *Bull. Geol. Soc. America*, Vol. 47 (1936), pp. 1091–1152; 10 pls., 3 figs.
———, *op. cit.* (1937c), pp. 1805–08.

of the range, in the Lomas de San Pablo, and in the hills along the east side of the Laguna de Mayran, may be summarized from top to bottom as follows.

	Thickness in Feet
Difunta formation	
16. Sandstone, shaly to thick-bedded, gray, interbedded with black shale; some beds varicolored; many beds of limestone conglomerate; lower 500 feet transitional into Parras shale. Fossils in upper beds include *Exogyra ponderosa* Roemer and *E. costata* var. *spinifera* Stephenson	12,000+
Parras shale	
15. Shale, fissile to nodular, calcareous, dark gray to black; very few beds of yellow, fine-grained sandstone; makes sharp contact with Indidura formation	2,800+
Indidura formation	
14. Limestone, thin-bedded to shaly, brownish black to yellowish brown. Near top contains *Peroniceras* aff. *P. subtricarinatum* D'Orbigny, *P.* cf. *P. bujuvaricum* Grossouvre, and *Inoceramus* cf. *I. convexus* Meek	100
13. Shale, brownish black to black, and some thin beds of black limestone that weather orange	340
12. Shale and thin beds of limestone, black; limestone forms one-third to one-half of the total and becomes more common toward top; contains many specimens of *Inoceramus labiatus* (Schlotheim)	700–740
11. Shale, grayish brown to black, rarely pinkish, fissile to nodular, calcareous, thinly laminated; a few beds of black limestone that weather yellow to bright orange	650–1,045
10. Limestone, thin-bedded, black, interbedded with shale, of which some is sandy, silty, or gypsiferous; shale is gray, yellow, or locally pinkish; most beds are thinly laminated; lower part of the Lomas de San Pablo furnished *Turrilites* cf. *T. scheuchzeri* var. *mexicana* Böse; lower contact abrupt.	350–575
Cuesta del Cura limestone	
9. Limestone, thin-bedded, wavy-bedded, compact, dark gray to black; some beds finely laminated; includes some gray, shaly partings and many thin lenses of black chert	210–240
Aurora limestone	
8. Limestone, thick- to medium-bedded, light to dark gray; shaly partings common; a few yellowish brown chert nodules in some beds; rudistids common throughout	420–740
La Peña formation	
7. Limestone, thin-bedded to shaly, gray to black, interbedded with some gray shale that becomes more abundant southward; contains many ammonites, including *Dufrenoya texana* Burckhardt	50–80
6. Limestone, thick- to thin-bedded, interbedded with some shale that becomes more common southward, light to dark gray	1,400+
Parritas formation	
5. Limestone, thin- to thick-bedded, grayish yellow to yellowish gray; weathers to light yellow spotted with pink; transitional into adjoining formations	1,120
Las Vigas formation	
4. Sandstone, thin-bedded to shaly, medium-grained, grayish yellow; weathers reddish yellow; interbedded with several units of medium- to thin-bedded yellowish or black limestone	240
3. Sandstone, as above, interbedded with considerable gray, greenish yellow shale, and red sandy shale; contains 30 feet of hard, siliceous limestone about 300 feet from base	705
Taraises formation	
2. Limestone, thin-bedded to shaly, light to dark gray, weathers light yellowish gray or cream; contains many ammonites	225–250
1. Limestone, thin- to medium-bedded, compact, dark to medium gray; weathers medium gray; poorly fossiliferous; makes sharp contact with underlying sandstones of La Casita formation	235–245
Total thickness	21,545–22,620

The lower member of the Taraises formation in the western part of the Sierra de Parras has not furnished ammonites older than Valanginian. From the lower

100 feet in Cañón de las Vacas were obtained *Dichotomites?*, *Thurmannites*, *Acanthodiscus*, *Olcostephanus*, and *Hoplitides?*.[296] These may be either of Valanginian or lower Hauterivian age, but, as the overlying upper member contains a large fauna of definite lower Hauterivian age, most of the lower member is probably of Valanginian age. The Las Vigas and Parritas formations and the lower member of the La Peña formation have not furnished fossils but must represent the upper Hauterivian, Barremian, and lower Aptian. The upper member of the La Peña formation contains a large fauna of the *Dufrenoya texana* zone.[297] Possibly the highest beds are basal Albian in age. On the basis of stratigraphic position and regional relationships the Aurora limestone is assigned to the lower and middle Albian. Of the five members of the Indidura formation near Parras, the lower two members are probably Cenomanian in age, although they have not furnished diagnostic fossils. The middle member is definitely Turonian, as it contains *Inoceramus labiatus* (Schlotheim). The next to the highest member is lithologically like the middle member and is provisionally considered Turonian. The highest member is assigned to the Coniacian, as it contains *Peroniceras*. Fossils have not been found in the Parras shale, but the overlying Difunta formation has furnished a large fauna belonging in the *Exogyra ponderosa* zone.

SIERRA DE JIMULCO OF SOUTHWESTERN COAHUILA

The Sierra de Jimulco (Fig. 9) has been studied in reconnaissance by Kellum[298] and Imlay.[299] The section exposed along the south wall of Cañón de San Pedro and Cañón Alamo south of Viesca, from top to bottom, follows.

	Thickness in Feet
Aurora limestone	
6. Limestone, thick- to medium-bedded, gray, rudistid-bearing. Not measured but at least	1,000+
La Peña formation	
5. Limestone, mostly thin-bedded to shaly; some units are thick-bedded, gray	443
4. Limestone, mostly medium- to thin-bedded, gray	557
Las Vigas formation	
3. Shale, light gray to pinkish, papery to fissile; contains some interbedded light gray, shaly limestone; near base are two hard units of ground shell conglomerate; grades downward into Taraises formation	800
Taraises formation	
2. Shale and shaly limestone, dark gray; weathers yellowish gray; contains ammonites	250
1. Limestone, at base medium- to thin-bedded and containing lenses of fine-grained, yellow sandstone; grades upward into shaly limestone; medium to dark gray, weathers gray to yellowish gray, lower contact abrupt	230

[296] R. W. Imlay, "Ammonites of the Taraises Formation of Northern Mexico," *Bull. Geol. Soc. America*, Vol. 49 (1938a), p. 551.

[297] R. W. Imlay, "Geology of the Western Part of the Sierra de Parras," *Bull. Geol. Soc. America*, Vol. 47 (1936), pp. 1121, 1122.

[298] L. B. Kellum, "Reconnaissance Studies in the Sierra de Jimulco, Mexico," *Bull. Geol. Soc. America*, Vol. 43 (1932), pp. 541–64; 15 figs.

[299] R. W. Imlay, "Studies of the Mexican Geosyncline," *Bull. Geol. Soc. America*, Vol. 49 (1938b), pp. 1667–70, 1673, 1678–84, 1688–90.
———, "Ammonites of the Taraises Formation of Northern Mexico," *Bull. Geol. Soc. America*, Vol. 49 (1938a), pp. 542, 549.

The upper member of the Taraises formation has furnished species of *Distoloceras*, *Olcostephanus*, and *Bochianites*[300] identical with species in the same member in the Sierra de Parras. The Las Vigas formation occupies the same position as in the Sierra de Parras. The La Peña formation is much thinner than in the Sierra de Parras and is extended down to the top of the Las Vigas formation, because there is little basis for subdivision at a higher level. The Aurora limestone is much thicker than in the Sierra de Parras. The Cuesta del Cura limestone occurs along the south side of the Sierra de Jimulco but has not been observed along the north side.

SIERRA DE SANTA ANA, NEAR LAS DELICIAS, COAHUILA

The Cretaceous section at the southern end of the Sierra de Santa Ana (Fig. 10), about 15 miles west of Las Delicias, has been studied by Kelly[301] and Jones[302] and may be summarized from top to bottom as follows.

	Thickness in Feet
Indidura formation	
7. Shale, buff, containing many veinlets of selenite; contains *Inoceramus labiatus* (Schlotheim)	40
6. Limestone, shaly to platy, and calcareous shale, gray, pink and red; contains many fossils, including ammonites *Romaniceras*, *Coilopoceras*, *Metoicoceras*, *Prionotropis*, and *Acanthoceras*	60
5. Shale, soft, buff; contains many selenite crystals; at base a thin unit of platy limestone and shale; contains *Mantelliceras* at top; *Exogyra plexa* Cragin and *Gryphaea washitaensis* var. *kellumi* Jones occur throughout	65
Aurora limestone	
4. Limestone, thick-bedded, gray; some black chert nodules; includes very few beds of gypsum or dolomite; contains some rudistids; grades downward into Cuchillo formation	1,000+
Upper part of Cuchillo formation	
3. Limestone, dolomite, gypsum, and chert nodules and lenses in alternating, lenticular, non-persistent beds; the thick-bedded limestone is gray, the thin-bedded limestone and dolomite are commonly brown, and the gypsum is white	1,500
Lower Cuchillo formation	
2. Limestone, massive, light gray, cliff-forming; contains *Orbitolina texana* (Roemer)	100–200
1. Limestone, shaly to sandy, interbedded with red to buff shale, sandstone, and some conglomerate; grades into overlying member, sharply separated from underlying Permian; contains Trinity mollusks, including *Dufrenoya* and *Douvilléiceras*	50–100
Total thickness	2,965

From the lower member of the lower Cuchillo formation were obtained[303] a typical Glen Rose fauna, including *Arctica mediale* (Conrad), *Pholadomya knowltoni* Hill, *P. sancti-sabae* Roemer, *Pleuromya? henselli* Hill, *Trigonia stolley* Hill, *Lunatia? pedernales* Hill (not Roemer), *Douvilléiceras*, and *Dufrenoya* cf. *D. justinae* (Hill). The upper member contains only *Orbitolina texana* (Roemer).

[300] R. W. Imlay, *op. cit.* (1938a), p. 549.

[301] W. A. Kelly, "Geology of the Mountains Bordering the Valleys of Acatita and Las Delicias," *Bull. Geol. Soc. America*, Vol. 47 (1936), pp. 1022–29.

[302] T. S. Jones, "Geology of Sierra de la Peña and Paleontology of the Indidura Formation," *Bull. Geol. Soc. America*, Vol. 49 (1938), pp. 86–93.

[303] W. A. Kelly, *op. cit.* (1936), p. 1024.

The presence of *Dufrenoya* in the lower member is excellent evidence of its upper Aptian age. The presence of *Orbitolina texana* in the upper member suggests an age as young as lower Albian, because the genus is very uncommon below the Albian in Mexico, or the United States. Correlation of the lower Cuchillo formation with the upper member of the La Peña formation of the Sierra de Parras seems apt.

The upper part of the Cuchillo formation has furnished only indeterminable Gryphaeas, gastropods, and corals, but its stratigraphic position suggests a lower to middle Albian age. The Aurora limestone has furnished poorly preserved rudistids and Neitheas, but its upper part must be of middle Albian age, as the overlying Indidura formation ranges from upper Albian to Turonian in age.

The lower member of the Indidura formation has furnished a few fossils, including among others *Gryphaea washitaensis* Hill, *G. washitaensis* var. *kellumi* Jones, *Exogyra plexa* Cragin, *Stoliczkaia?*, and *Mantelliceras*. *Gryphaea washitaensis* occurs throughout the member, but *Mantelliceras* occurs only in the highest part.[304] The presence of *Mantelliceras* is satisfactory evidence of Cenomanian age. *Stoliczkaia* might be either latest Albian or early Cenomanian. As *Gryphaea washitaensis* and *Exogyra plexa* in Texas occur in beds of middle and upper Albian ages, the forms from Coahuila were considered by Jones to represent the upper Albian, perhaps including beds as old as the Kiamichi shale. However, *E. plexa* is scarcely separable from immature forms of *E. arietina* Roemer, which ranges as high as the Buda (lower Cenomanian) and *G. washitaensis* is a long-ranging species of little value for correlation. As the lower member rests with apparent conformity on the Aurora limestone, the upper Albian is probably represented, but it might have been a time of non-deposition.

The middle member has furnished a large fauna of Eagle Ford ammonites, associated with echinoids and oysters that in Texas occur in the Washita group.[305] Most of the ammonites, including *Romaniceras*, *Coilopoceras*, and *Prionotropis* are of middle or upper Turonian age, but *Metoicoceras* might be older. Jones[306] concluded that the association of fossils that normally occur in the late Comanche series with fossils that normally occur in the early Gulf series could be explained only by continuous deposition in the Coahuila area while erosion was taking place in the United States. Thus, the oysters and echinoids would have a longer range in Mexico than in the United States. Evidently the middle member of the Indidura formation was deposited very slowly and possibly includes many diastems representing nondeposition.

The upper member has furnished *Inoceramus labiatus* (Schlotheim) and is upper Turonian in age, but may not represent the highest Turonian.

[304] T. S. Jones, *op. cit.*, (1938), pp. 89, 90, 126.

[305] *Ibid.*, p. 91.

[306] *Ibid.*, p. 92.

SIERRA DE LA PEÑA, SOUTHERN COAHUILA

The Sierra de la Peña (Fig. 9) was studied in detail by Jones,[307] whose descriptions of the Cretaceous section may be summarized from top to bottom as follows.

	Thickness in Feet
Indidura formation	
4. Shale, fissile, calcareous, dark gray, and some black laminated limestone that weathers gray, buff, and orange; includes a few beds of sandstone and sandy shale at various intervals; minor amounts of secondary gypsum; contains *Inoceramus labiatus* (Schlotheim)	1,500+
3. Marl, sandy, gypsiferous, buff to gray; includes some thin beds of nodular limestone; contains many fossils, including *Romaniceras* and *Metoicoceras*	8
2. Limestone, thin-bedded, laminated, light to dark gray, inter-bedded with dark gray, sandy, calcareous shale; some gypsum flakes and veinlets; no fossils	15–20
Aurora limestone	
1. Limestone, thick-bedded, hard, light to dark gray, interbedded with gypsum, dolomite, and dolomitic limestone; some beds contain chert nodules; rudistids common	435+
Total thickness	1,963+

The Aurora limestone of the Sierra de la Peña is correlated[308] with the Edwards limestone of Texas on the basis of the presence of *Gryphaea marcoui* Hill and Vaughan, *Pecten* (*Neithea*) *subalpinus* (Böse), and many rudistids closely related to forms in the Edwards such as *Toucasia texana* (Roemer). The lower member of the Indidura formation has not furnished fossils. The middle and upper members contain many species in common with the same members in the Sierra de Santa Ana and are considered of the same age.

MOUNTAINS WEST OF LAGUNA DISTRICT, EASTERN DURANGO

The geology of the Sierra de Mapimí, Sierra de las Noas, and Sierra de Hispaña west and northwest of Torreon (Fig. 9) has been studied by Kellum[309] and Singewald.[310] Their descriptions of the Cretaceous section, partly modified by the writer,[311] may be summarized from top to bottom as follows.

	Thickness in Feet
Indidura formation	
8. Shale and thin-bedded limestone interbedded, generally thinly laminated, gray to black; thin, basal conglomerate of limestone pebbles noted in Cañón del Indio of Sierra de las Noas; contains *Inoceramus* aff. *I. latus* Elbert. Estimated thickness of several thousand feet.[312]	3,000 (?)

[307] *Ibid.*, pp. 69–150.

[308] T. S. Jones, *op. cit.* (1938), p. 81.

[309] L. B. Kellum, "Geology of the Mountains West of the Laguna District," *Bull. Geol. Soc. America*, Vol. 47 (1936a), pp. 1039–90; 14 pls., 2 figs.

[310] Q. D. Singewald, "Igneous Phenomena and Geologic Structure near Mapimí," *Bull. Geol. Soc. America*, Vol. 47 (1936), pp. 1153–76; 5 pls., 1 fig.

[311] R. W. Imlay, "Studies of the Mexican Geosyncline," *Bull. Geol. Soc. America*, Vol. 49 (1938b), pp. 1687–89.
———, "Neocomian Faunas of Northern Mexico," *Bull. Geol. Soc. America*, Vol. 51 (1940a), pp. 123, 124, 133, 134.

[312] Q. D. Singewald, *op. cit.* (1936), p. 1157.

	Thickness in Feet
Aurora limestone	
7. Limestone, medium- to thick-bedded, dense, dark gray; some beds dolomitic; locally black chert nodules abundant; contains rudistids and miliolids[313]	2,000 (?)
La Peña formation	
6. Limestone, medium- to thick-bedded, gray; at top a marly unit about 50 feet thick contains *Dufrenoya*, *Cheloniceras*, *Hyacanthoplites*, *Exogyra quitmanensis* Cragin, and other upper Aptian fossils. Thickness not measured	?
Parritas formation	
5. Limestone, medium- to thick-bedded, siliceous, yellow to yellowish gray, or less commonly pink; some intercalated lenses of yellow, gray or red sandstone and gray, yellow, or green shale	248+
Las Vigas formation	
4. Sandstone, red, fine-grained, and interbedded reddish gray arkose and red or green sandy shale	112–300
Taraises formation	
3. Limestone, thin-bedded, light gray, siliceous in lower half; contains a few beds of yellow quartz sandstone	335
2. Limestone, siliceous to marly, buff, gray, and green, interbedded with gray to reddish arkose that is locally conglomerate; some shale partings and quartz sandstone lenses	325
Carbonera formation	
1. Sandstone, shaly, alternating with units of shale, gray; weathers buff; locally greenish gray, coarse arkose basally; middle part contains *Exogyra reedi* Imlay and gigantic *Thurmannites* of Valanginian age; overlies conglomeratic quartz sandstone of upper Jurassic	740–1,300

The Carbonera formation corresponds with unit 5 of the Puerto de Soldados section and unit B of the Cuesta del Carbonera section described by Kellum.[314] Its middle part is characterized by the presence of *Exogyra reedi* Imlay and giant species of *Thurmannites* similar to *T. novihispanicus* Imlay and *T. miquihuanensis* Imlay from the Miquihuana area of Tamaulipas. The beds with *Thurmannites* near Miquihuana appear to be lower stratigraphically than the beds containing abundant *Rogersites* and *Valanginites* and to represent the middle Valanginian. Associated with the *Thurmannites* in the Carbonera formation are fragments questionably referred to *Blanfordiceras* and *Berriasella*, which forms indicate an age older than upper Valanginian. The lower part of the Carbonera formation has furnished two distorted ammonites probably belonging to *Spiticeras* and *Thurmannites*[315] and suggesting Berriasian age.

The Taraises formation corresponds with units 3 and 4 of the Puerto de Soldados section and to unit A and overlying beds of the Cuesta del Carbonera section as described by Kellum.[316] The upper member (unit 3) is very similar to the upper member of the Taraises formation of the Sierra de Parras. The lower member (units 4 and A) differs from the lower member of the Taraises formation of the Sierra de Parras by being more siliceous and by containing sandstone and arkose. The lower member in Cañón Alamo of the Sierra de Jimulco is intermediate in this respect.

[313] L. B. Kellum, *op. cit.* (1936a), p. 1071.
Q. D. Singewald, *op. cit.* (1936), p. 1156.

[314] L. B. Kellum, *op. cit.* (1936a), pp. 1053, 1054, 1058, 1059, 1067–69.

[315] R. W. Imlay, *op. cit.* (1940a), pp. 133, 134.

[316] L. B. Kellum, *op. cit.* (1936a), pp. 1058, 1069.

The Las Vigas and Parritas formations correspond, respectively, with unit 2 and the lower part of unit 1 of the Puerto de Soldados section described by Kellum.[317] They differ from the same formations in the western part of the Sierra de Parras by being somewhat thinner. The overlying La Peña, Aurora, and Indidura formations correspond closely with the same formations in the Sierra de Parras sections. The thin conglomerate at the base of the Indidura formation in Cañón del Indio possibly signifies a disconformity.

SIERRA DEL ROSARIO, EASTERN DURANGO

The Sierra del Rosario has been studied by Kellum,[318] but the details have not been published. The section includes the Aurora and La Peña formations, and some underlying sandstones possibly Neocomian in age. Burckhardt studied the section exposed along the Río Nazas, at the south end of the range, and described some upper Aptian-lower Albian fossils.[319] His section may be described from top to bottom as follows.

	Thicknesss in Feet
Aurora limestone	
5. Limestone, thick-bedded, gray to dark gray, some yellow to black chert concretions and lenses of black chert	1,000–1,300±
La Peña formation	
4. Limestone and marly limestone, dark gray to brown, alternating with beds of black chert; contains *Hypacanthoplites*, *Cheloniceras*, and *Douvilléiceras*	100±
3. Limestone, marly, gray to yellow, interbedded with dark gray shale; contains *Pseudohaploceras*, *Uhligella*, *Pedioceras*, *Dufrenoya*, *Hypacanthoplites*, *Columbiceras*, *Cheloniceras*, *Ammonitoceras*	100±
2. Limestone, massive, gray; contains caprinids, Nerineas, corals, and bivalves	100±
1. Limestone, thick-bedded, compact, gray; contains *Requienia* and other bivalves; some thin, marly intercalations contain *Ostrea* and *Exogyra*; some beds, especially near summit, contain nodules and lenses of black chert. Base not exposed	1,300±

The upper 1,000 to 1,300 feet of thick-bedded limestone belong to the Aurora limestone, and the remainder of the section to the La Peña formation. The upper part of the La Peña formation is characterized by a marly unit whose lower part contains upper Aptian fossils of the *Dufrenoya texana* zone, and whose upper part contains lower Albian fossils belonging mainly to the genera *Hypacanthoplites* and *Douvilléiceras*.

SAN PEDRO DEL GALLO, EASTERN DURANGO

The San Pedro del Gallo area (Fig. 9) was studied by Angermann[320] and

[317] L. B. Kellum, "Geology of the Mountains West of the Laguna District," *Bull. Geol. Soc. America*, Vol. 47 (1936a), pp. 1057, 1058, 1070.

[318] L. B. Kellum, "Sierra del Rosario, Durango," *Bull. Geol. Soc. America*, Vol. 52 (1941), p. 1913.

[319] Carlos Burckhardt, "Faunas del aptiano de Nazas (Durango)," *Bol. Inst. Geol. México*, Núm. 45 (1925). 71 pp., 10 pls.
———, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 138–41.

[320] Ernesto Angermann, "Explicación del plano geológico de la región de San Pedro del Gallo, Estado de Durango," *Parergones Inst. Geol. México*, T. 2 (1907), pp. 5–14, map.

Burckhardt[321] and was briefly examined by the writer. The Cretaceous section from top to bottom follows.

	Thickness in Feet
8. Marl and shale, gray or yellow; contains *Acanthoceras* cf. *A. laticlavium* Sharpe (equals *Sharpeiceras*)	?
Cuesta del Cura limestone	
7. Limestone, thick- to thin-bedded, gray to yellow, with many intercalations and beds of black chert; contains uncoiled ammonites and belemnites	820±
La Peña formation	
6. Marl and shale, yellowish gray, alternating with beds of gray to brown limestone and black chert; contains *Douvilléiceras* cf. *D. nodosocostatum* D'Orbigny and small belemnites	150±
5. Limestone, mostly thick-bedded, compact, gray, rarely yellow; some nodules of yellow to orange chert; upper part contains *Costidiscus* cf. *C. recticostatus* D'Orbigny and *Desmoceras* cf. *D. boutini* Mathéron (*Melchiorites?*); lower part contains *Holcodiscus;* basal beds contain large belemnites	1,000–1,300
Parritas formation	
4. Limestone, medium-bedded, compact, gray, reddish, or yellowish, alternating with thin beds of marl, marly limestone, and shale of the same color; locally contains limonite nodules or intercalations of yellow to orange chert; contains *Leptoceras* sp.	820±
Taraises formation	
3. Limestone, medium- to thin-bedded, marl, and shale, gray to yellowish gray; some limonite nodules and chert lenses; contains *Dichotomites*, *Olcostephanus*, *Kilianella*, *Neocomites*, *Bochianites*, and *Leptoceras*	655
2. Limestone, medium- to thin-bedded, compact, gray	245
1. Limestone, shaly to thin-bedded, gray to reddish gray, contains *Spiticeras*, *Subthurmannia*, *Protocanthodiscus*, *Neocomites*, and *Kilianella*	120
Total thickness	3,765±

The basal 120 feet of the Taraises formation on the Cerro de Aguajito, about 2 kilometers northeast of San Pedro del Gallo, has furnished a faunule of Berriasian age, including *Spiticeras*, *Subthurmannia*, *Protocanthodiscus*, and *Neocomites*. The same unit on the Cerro del Panteón immediately west of the town has furnished *Kilianella* and an olcostephanid which suggests a Valanginian age. The upper 655 feet of the Taraises formation is probably lower Hauterivian in age as suggested by the presence of *Dichotomites* and by its stratigraphic position.

The overlying yellowish to reddish limestone, marl, and shale are similar to the Parritas formation of the western part of the Sierra de Parras and of the mountains west of the Laguna District, but they probably include equivalents of the Las Vigas formation. The same formation cropping out[322] northwest of San Pedro del Gallo between Cerro del Volcán and the Cerritos de los Magueyitos contains some green sandstone.

The La Peña formation has a twofold division as in the Sierra de Parras. The

[321] Carlos Burckhardt, "Estudio geológico de la región de San Pedro del Gallo, Durango," *Parergones Inst. Geol. México*, T. 3 (1910a), pp. 307–57, chart, plate, geologic map.

———, "Faunes jurassiques et crétaciques de San Pedro del Gallo (État de Durango, México), *Bol. Inst. Geol. México*, Núm. 29 (1912). 260 pp., 46 pls.

———, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 127, 129, 131–34, 144, 167, 174, 175.

[322] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 127, 144.

lower member is Barremian and lower Aptian in age, as *Holcodiscus* is a characteristic Barremian ammonite, and *Costidiscus* similar to *C. recticostatus* D'Orbigny is characteristic of the upper Barremian and lower Aptian. The upper member has furnished only a single specimen of *Douvilléiceras* similar to *D. nodosocostatum* D'Orbigny, a characteristic lower Albian marker, but it seems likely that the upper Aptian is represented by the lower part of the member.

The overlying limestone containing many beds of black chert is similar to the Cuesta del Cura limestone of the Melchor Ocampo area of northern Zacatecas and undoubtedly is equivalent to both the Aurora limestone and the Cuesta del Cura limestone of the Sierra de Parras. Uncoiled ammonites are characteristic of the Cuesta del Cura limestone and chert facies. Burckhardt[323] reports that this facies is associated with green to brown sandstone and dark shale in the Cerritos de los Magueyitos northwest of San Pedro del Gallo and in the Sierra de San Francisco about 7 miles east of San Pedro del Gallo, but the writer considers that Burckhardt has misinterpreted the sections in those areas, and that the sandy beds are actually upper Neocomian in age.

The Indidura formation, observed only on the Mesa del Cardenche, a few miles southeast of San Pedro del Gallo, contains an ammonite referable to *Sharpeiceras* of the Cenomanian.

PARRAL-JIMENEZ-CAÑAS AREA, SOUTHERN CHIHUAHUA

In the valley of Parral and near Jimenez are exposed gray, yellow, brown, and black shale containing some thin beds of limestone that have furnished uncoiled ammonites characteristic of the upper Albian of Mexico.[324] Near Cañas, about 23 miles southeast of Jimenez, Böse[325] found a few pelecypods and echinoids that occur elsewhere in the Fredericksburg group and are presumably middle Albian in age.

SIERRA MOJADA-MOHÓVANO-PIEDRA DE LUMBRE AREA

The geology of the Sierra Mojada area (Fig. 8) has been studied briefly by Ramírez,[326] Böse,[327] Haarmann,[328] and Böse and Cavins,[329] and some of the Turo-

[323] Carlos Burckhardt, *op. cit.* (1930), pp. 174, 175.

[324] Paul Waitz, "Esquisse géologique et petrographique des environs de Hidalgo del Parral," *International Geol. Congress X, Mexico, Guide Excursion 21* (1906), pp. 2–5, map.
Carlos Burckhardt, *op. cit.* (1930), p. 174.

[325] Emil Böse, "Monografia geológica y paleontólogica del Cerro de Muleros cerca de Ciudad Juárez y descripción de la fauna cretácea de la Encantada, Placer de Guadalupe, Estado de Chihuahua," *Bol. Inst. Geol. México,* Núm. 25 (1910b), pp. 50, 128, 132, 152.

[326] Santiago Ramírez, "Informe que como resultado de su exploración en la Sierra Mojada, México," *Anales Ministerio de Fomento,* T. 3 (1877), pp. 633–58, Pls. 1–4.

[327] Emil Böse, "Neue Beiträge zur Kenntnis der mexikanischen Kreide," *Centralbl. Min. Geol. und Paläont.* (1910a), pp. 616–22, 652–62.

[328] Erich Haarmann, "Geologische Streifzüge in Coahuila," *Zeitschr. Deutsche geol. Gesell.*, Vol. 65, Monatab. 1 (1913), pp. 18–47.

[329] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), pp. 28, 29.

nian fossils have been described by Böse.[330] Specimens of *Pervinquieria* and *Radiolites?*, figured by Ramírez,[331] indicate the presence of upper Albian.[332] A section measured by F. L. Wingfield in the mountain west of the town of Sierra Mojada contains upper Aptian fossils near its base, according to determinations by the writer. This section, not published previously, may be described from top to bottom as follows.

	Meters	*Feet*
Indidura formation		
16. Shale and thin-bedded limestone. Contains *Romaniceras, Turrilites, Gryphaea washitaensis* var. *kellumi* Jones, *Plicatula subgurgitis* Böse, *Sauvagesia, Inoceramus labiatus* (Schlotheim), *Pteria aguilerae* (Böse), *Inoceramus* cf. *I. fragilis* Hall and Meek	90	295
Cuesta del Cura limestone		
15. Limestone, thin- to medium-bedded, gray; some beds dolomitic; contains white and pink chert	300–350	984–1,148
Aurora limestone		
14. Limestone, white to gray; some beds dolomitic	125	
13. Limestone, dolomitic, brown, porous	90	
12. Limestone, dolomitic, dense, gray	110	
11. Limestone, gray, fossiliferous	20	
10. Limestone, thick-bedded, soft, porous, gray to white	25	1,738
9. Limestone, massive, porous	40	
8. Limestone, dense, gray, some chert	25	
7. Limestone, partly dolomitic; some small chert nodules; is main ore zone	45	
6. Limestone, medium-bedded, dense, gray; has shaly partings	50	
La Peña formation		
5. Limestone, thin-bedded, and shale, black; contains *Cheloniceras* aff. *C. aequicostatum* Burckhardt, *C. aequicostatum* Burckhardt, *C.* aff. *C. stoliczkanum* (Gabb) in Burckhardt, *Ammonitoceras? cornutum* Burckhardt, *Hypacanthoplites*, and *Exogyra quitmanensis* Cragin	20–40	
4. Limestone, dolomitic	2–10	466–558
3. Limestone, partly dolomitic, gray to pink	120	
Patula arkose (?)		
2. Sandstone and shale in thin beds, becoming conglomeratic at base	5–30	
1. Conglomerate; material ranges from one-fourth of an inch to ten inches in diameter; and consists of rhyolite, granite, basalt, and some limestone	275	918–1,000
Total thickness	1,342–1,445	4,740±

The foregoing section is rather similar to that at Barril Viejo in east-central Coahuila and was probably deposited just west of the margin of the Coahuila platform, as indicated by the absence of gypsiferous beds in the lower and middle Albian and by the presence of chert-bearing limestone in the upper Albian. The upper part of the La Peña formation carries a typical upper Aptian fauna, although lacking specimens of *Dufrenoya*. The stratigraphic position of the fossils figured by Ramírez is not known.

The Indidura formation contains typical Turonian fossils similar to those in the Sierra de Santa Ana and Sierra de la Peña of southern Coahuila.[333] The fossils are included in five collections, but the stratigraphic positions of the collections are not known.

[330] Emil Böse, "On a New Ammonite Fauna of the Lower Turonian of Mexico," *Univ. Texas Bull. 1856* (1918), pp. 173–252; 9 pls., 7 figs.

[331] Santiago Ramírez, *op. cit.* (1877), Pl. 1.

[332] Carlos Burckhardt, *op. cit.* (1930), p. 175.

[333] T. S. Jones, "Geology of Sierra de la Peña and Paleontology of the Indidura Formation," *Bull. Geol. Soc. America*, Vol. 49 (1938), pp. 69–150; 13 pls., 4 figs.

On the Cerro del Macho, near Mohóvano, about 42 miles south of the town of Sierra Mojada, occurs an interesting section of lower Turonian rocks,[334] which, from top to bottom, is as follows.

	Meters
3. Limestone, hard, gray; contains *Vascoceras, Neoptychites, Hoplitoides?, Inoceramus labiatus* (Schlotheim)	5–6
2. Marl, dark gray; contains *Mammites, Pseudaspidoceras, Vascoceras, Fagesia*	2.5
1. Marl, and shaly limestone, yellow and red; contains *Metoicoceras* aff. *M. whitei* Hyatt, *Exogyra* cf. *E. olisiponensis* Sharpe, and others	2.
	10. ±

Böse[335] considered that the upper two beds belonged in the lower Turonian, but that the basal bed might be as old as upper Cenomanian. Burckhardt[336] considered all three beds to be lower Turonian.

Another exposure of lower Turonian is known about 9 miles west of Piedra de Lumbre, Coahuila, or about 50 miles southeast of the town of Sierra Mojada. The section, according to Böse and Cavins,[337] from top to bottom, follows.

	Feet
7. Shale, gray	?
6. Limestone, nodular, hard; contains undetermined echinoderms and ammonites	52
5. Limestone, nodular, marly, gray	46
4. Limestone, thin-bedded, somewhat marly, gray; contains *Vascoceras, Fagesia, Neoptychites, "Hoplitoides," Metoicoceras* cf. *M. whitei* Hyatt, and *Inoceramus labiatus* (Schlotheim)	39
3. Shale and marl, gypsiferous, gray; contains undetermined ammonites	?
2. Limestone, thin-bedded; contains many *Gryphaea washitaensis* Hill	?
1. Limestone, thick-bedded, dark gray	?

The thick-bedded limestone at the base corresponds with the Aurora limestone. The overlying thin-bedded limestone containing *Gryphaea washitaensis* Hill is probably equivalent to the lower member of the Indidura formation of the Las Delicias area,[338] to the Cuesta del Cura limestone of the Sierra de Parras, and to the Washita group of Texas. The gypsiferous shale and marl of unit 3 were correlated by Böse and Cavins[339] with the basal bed on Cerro del Macho near Mohóvano, the limestones of units 4 to 6 with the lower Turonian, and the shale at the top with the upper Turonian.

Beds containing silicified wood and dinosaur remains were discovered by Haarmann[340] near Soledad and at other places along the railroad between Escalón, Chihuahua, and Sierra Mojada, Coahuila. They consist basally of red, green, and gray marl, and higher up of sandstone, conglomerate, shale, and sandy shale. The

[334] Erich Haarmann, "Geologische Streifzüge in Coahuila," *Zeitschr. Deutsche geol. Gesell.*, Vol. 65, Monatab. 1 (1913), pp. 18–47.
Emil Böse, "On a New Ammonite Fauna of the Lower Turonian of Mexico," *Univ. Texas Bull. 1856* (1918), pp. 173–252; 9 pls., 7 figs.

[335] Emil Böse, *op. cit.* (1918), pp. 183–92.

[336] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 222.

[337] Emil Böse and O. A. Cavins, *op. cit.* (1927), p. 29.

[338] T. S. Jones, *op. cit.* (1938), pp. 87, 89, 90.

[339] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), p. 29.

[340] Erich Haarmann, *op. cit.* (1913), p. 25.

sandstones are locally cross-bedded, and at many places are quartzitic. The conglomerate contains limestone, andesite, and rhyolite, and the fossil remains. Burckhardt[341] considers the beds to be late Upper Cretaceous in age contemporaneous with the dinosaur-bearing beds of the Big Bend area of Texas.[342]

SANTA ELENA AREA OF EASTERN CHIHUAHUA

The geology of the Santa Elena area (Figs. 8 and 16) has not been described. An unpublished section measured by F. L. Wingfield, from top to bottom, follows.

	Meters
37. Sandstone, calcareous, reddish yellow; other lithologic types may be present; near top contains *Baculites* cf. *B. undatus* Stephenson, *Gyrodes* sp., *Cymbophora* sp., *Turritella trilira* Conrad	610
36. Shale and marl; thin bed of brown limestone at base; about 60 feet above base occur *Stoliczkaia* cf. *S. texana* (Cragin) and *Turrilites* sp.	144
35. Limestone and shale, gray to white	123
34. Covered. Probably shale	102
33. Limestone, dense, gray; some chert and shale	165
32. Shale and limestone; lower fourth has furnished *Prohysteroceras* cf. *P. austinense* (Roemer), *P.* n. sp., *Turrilites* sp.	135
31. Shale, marl, and thin-bedded limestone; near middle occurs *Oxytropidoceras* cf. *O. kiowanum* (Twenhofel), *Oxytropidoceras* sp. juv., *Hysteroceras* aff. *H. varicosum* (J. de C. Sowerby), *Hysteroceras* sp., *Beudanticeras* sp., *Lechites* aff. *L. communis* Spath, *Plicatula* sp., *Kingena* sp., *Salenia* sp., and *Enallaster* sp.	95
30. Shale, marl, and thin-bedded limestone; thinner-bedded than overlying unit; contains many ammonites	60
29. Limestone, thin-bedded, dense, gray	180
28. Limestone, thin-bedded, and shale, gray	125
27. Limestone, thin- to medium-bedded, dark gray; a few chert nodules	440
26. Shale	10
25. Limestone, thin-bedded, dense, dark gray	105
24. Shale and limestone; contains *Hypacanthoplites*, *Acanthoplites*, *Dufrenoya?*, and *Exogyra*	26
23. Limestone	5
22. Shale and limestone; contains *Hypacanthoplites* and *Lucina*	48
21. Shale and limestone	18
20. Limestone	5
19. Limestone, shaly	60
18. Limestone	5
17. Limestone, thin-bedded to shaly	96
16. Limestone	5
15. Shale and limestone	50
14. Limestone, thin-bedded, gray	30
13. Gypsum and shale	65
12. Shale and limestone	15
11. Limestone	33
10. Gypsum	92
9. Gypsum and shale	70
8. Limestone	6
7. Gypsum and shale, fossiliferous	95
6. Limestone	10
5. Shale and gypsum	8
4. Limestone	32
3. Shale and gypsum	10
2. Limestone	5
1. Shale, gypsum, and thin-bedded limestone	290
Total thickness	3,373 (11,063 feet±)

[341] Carlos Burckhardt, *op. cit.* (1930), p. 259.

[342] W. S. Adkins, "The Mesozoic Systems in Texas" in "The Geology of Texas," Vol. 1, Stratigraphy, *Univ. Texas Bull. 3232*, Pt. 2 (1933), pp. 508, 509.

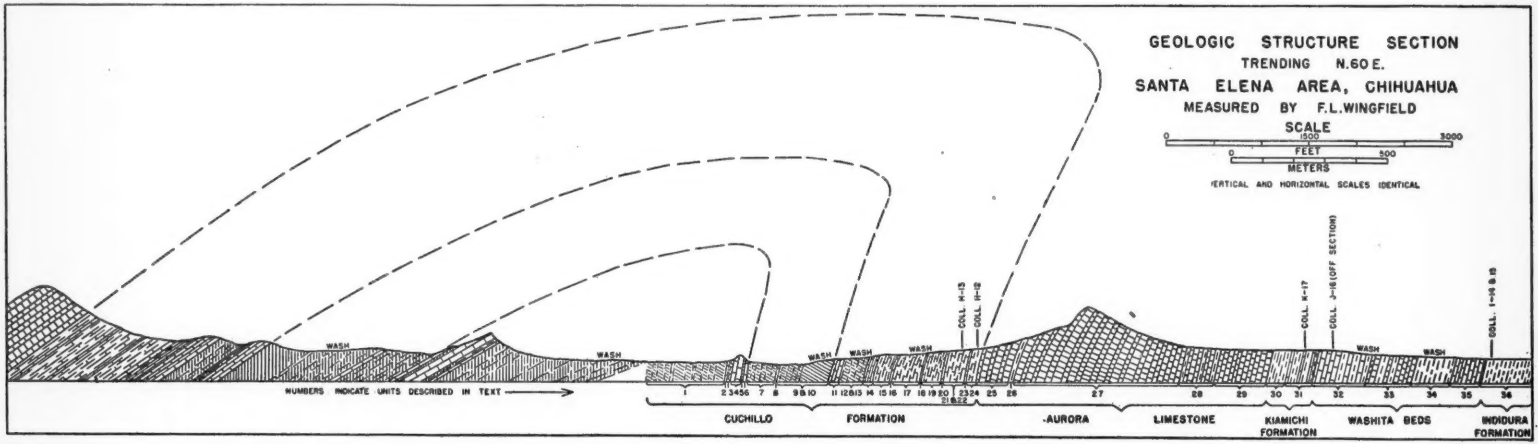


FIG. 16.—Structure section of Santa Elena area in eastern Chihuahua. Measured by F. L. Wingfield. Not published previously.

The description of this section may be summarized as follows.

		Meters	Feet
37.	Sandstone, calcareous, reddish yellow; contains fossils of Taylor or Navarro age	610	2,000
36.	Shale and marl; lower fourth contains ammonites of late Washita age	144	472
35–32.	Limestone and shale; unit 32 contains ammonites of Duck Creek or Fort Worth age	525	1,722
31–30.	Shale, marl, and thin-bedded limestone; upper part contains upper Fredericksburg ammonites	155	509
29–28.	Limestone, thin-bedded, and some shale	305	1,000
27–25.	Limestone, thin- to medium-bedded; contains a few chert nodules; one thin unit of shale in lower fifth	555	1,820
24–14.	Limestone, thin-bedded to shaly, and shale; upper 258 feet contains ammonites of lower Albian or possibly upper Aptian age	348	1,141
13–1.	Gypsum and shale and a few thin units of thin-bedded limestone; units 2–6 are ore-bearing	731	2,398
		3,373	11,062

The foregoing section is noteworthy for the tremendous thickness of rocks of late Comanche age and for the considerable lithologic differences from the section in the Sierra de Mojado, only about 50 miles south. The sandstones of unit 37 possibly correspond with the Soledad beds near Mohóvano, at the corner of Chihuahua, Durango, and Coahuila, or with the Difunta formation of the Parras Basin of southern Coahuila. The shale and marl of unit 36 possibly includes the Indidura formation, but the lower fourth is late Comanche in age. Units 35 to 32 correspond with the greater part of the Washita group of Texas and apparently are similar lithologically. They are entirely unlike the Cuesta del Cura limestone of the central part of the Mexican geosyncline. Units 31 and 30 on the basis of fossils are equivalent to the Kiamichi formation of Texas. Units 29 to 25 must be equivalent to the Aurora limestone of northern Mexico, but lithologically only units 27–25 resemble the Aurora limestone. Units 24 to 14 are similar in appearance to the upper member of the La Peña formation of the Sierra de Parras section. The ammonites collected from units 24 and 22 are similar to the lower Albian forms of *Hypacanthoplites* and *Acanthoplites* found by Burckhardt[343] in the Mazapil area of Zacatecas. The absence of species of *Cheloniceras* and *Ammonitoceras* likewise suggests lower Albian age. Only one poorly preserved external mold shows any resemblance to *Dufrenoya*. However, it seems likely that the upper Aptian is represented by the greater part of the limestone and shale in units 21 to 14. The 2,398 feet of gypsiferous beds below unit 14 are assigned to the lower Aptian on the basis of stratigraphic position, and the consideration that gypsum is uncommon in beds of Neocomian age in northern Mexico.

SIERRA DE LA PAILA, EASTERN COAHUILA

The Cretaceous section exposed in the Sierra de la Paila and along its southern and eastern margins[344] may be summarized from top to bottom as follows.

[343] Carlos Burckhardt, "La faune jurassique de Mazapil avec un appendice sur les fossiles du crétacique inférieur," *Bol. Inst. Geol. México*, Núm. 23 (1906c), pp. 191–94, Pls. 42, 43.

[344] Emil Böse, "Excursions dans les environs de Monterrey et Saltillo," *International Geol. Congress X, Mexico, Guide Excursion 29* (1906d), pp. 2, 3.

Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 175, 176, 190, 191.

Cuesta del Cura limestone

2. Limestone, thin-bedded, gray to black; near Hacienda La Luz at the eastern base of the Sierra de la Paila, occur *Desmoceras, Hoplites, Turrilites* group of *T. costatus* Lamarck, and *Baculites* aff. *B. baculoides* Mantell

Aurora limestone

1. Limestone, thick-bedded, light to dark gray; contains *Nerinea*, caprinids, and *Toucasia* cf. *T. texana* (Roemer); very thick

MOUNTAINS OF EAST-CENTRAL COAHUILA

The Lower Cretaceous rocks exposed in the deeply eroded anticlinal uplifts of east-central Coahuila[345,346] are about 9,000 feet thick (Fig. 13). The Neocomian is represented by arkose, shale, limestone, and minor amounts of gypsum. Its sediments become finer and more calcareous eastward from the Coahuila Peninsula. The Aptian is represented by arkose, shale, marl, dolomite, dolomitic limestone, and considerable gypsum, but contains dolomite and gypsum only in areas on or near the site of the Coahuila Peninsula. The lower and middle Albian is represented by the rudistid-bearing Aurora limestone and probably by the upper part of the Cuchillo formation. The section in the Valle de Muralla, measured by L. B. Kellum,[347] may be described from top to bottom as follows.

	Thickness in Feet
Aurora limestone	
9. Limestone, compact, gray; top has gray chert and ferruginous concretions; base has shaly limestone	2,255
La Peña formation (?)	
8. Limestone, shaly, gray, alternating with gray to red shale; some beds of black chert, and some reddish gray, fine-grained sandstone; contains *Sonneratia, Parahoplites,* and *Douvilléiceras* of the lower Albian	138
7. Covered	289
6. Limestone, compact, siliceous, generally dark gray; in places contains beds of shaly limestone and shale; at top has chert nodules, at base has intercalations of gray and orange sandstone	1,080
5. Covered	607
Patula arkose	
4. Sandstone, yellowish gray, interbedded with coarse to fine-grained, green arkose; green shale at base	203
3. Sandstone, arkose, and shale; sandstone is yellow, black, green; arkose is thick-bedded, locally conglomeratic, gray, white, red, yellowish brown; shale is red to green	2,286
2. Arkose, red, some beds conglomeratic, generally cross-bedded; in places passing into red and green shale which predominates at base	764
Barril Viejo shale	
1. Shale, greenish gray, in places sandy, alternating with gray limestone and reddish, greenish, or gray sandstone that is locally arkosic, weathers brown; contains many middle Neocomian bivalves; base not exposed	797
Total thickness	5,419±

The generalized section in Barril Viejo, measured by Wm. G. Kane,[348] from top to bottom, follows.

[345] Carlos Burckhardt, *op. cit.* (1930), pp. 83, 143–47, 176, 190, 191.

[346] R. W. Imlay, "Neocomian Faunas of Northern Mexico," *Bull. Geol. Soc. America*, Vol. 51 (1940a), pp. 120–23.

[347] Carlos Burckhardt, *op. cit.* (1930), p. 146.

[348] R. W. Imlay, *op. cit.* (1940a), p. 121.

	Thickness in Feet
Aurora limestone (in part)	
5. Limestone, thick-bedded, gray; basal marly beds contains *Dufrenoya texana* Burckhardt	3,500
Patula arkose	
4. Graywackes and arkoses, green and brown	1,500
Padilla limestone	
3. Limestone, thick-bedded, dark gray, containing some arkosic impurities near base	5
Barril Viejo shale	
2. Shale, dark gray, calcareous; contains many bivalves and ammonites of lower Hauterivian age, including *Leopoldia*, *Acanthodiscus*, and *Dichotomites*	100
San Marcos arkose	
1. Arkose, granitic, coarse, red; contains red-stained granite boulders as much as 30 inches in diameter	700
Total thickness	8,850±

The generalized section in the Potrero de Menchaca, measured by Wm. G. Kane,[349] from top to bottom, follows.

	Thickness in Feet
Aurora limestone (in part)	
8. Limestone, thick-bedded, gray. Not measured	3,500 (?)
Cuchillo formation	
7. Gypsum, bedded, with intercalations of limestone and shale; distinctive beds of compact, honey-combed, yellow limestone; several units of gray limestone similar to overlying Aurora limestone; lowest member is very resistant yellow-gray limestone	1,099
La Mula shale	
6. Shale and sandy shale, gray, green, pink, purple, and yellow, easily eroded	794
Padilla limestone	
5. Limestone, thick-bedded, dark gray; contains large gastropods	50 (?)
Barril Viejo shale	
4. Shale, dark gray, calcareous; contains many middle Neocomian fossils	843
San Marcos arkose	
3. Arkose similar to that at Barril Viejo but without granitic boulders and considerably finer-grained; coarser-grained than equivalent beds at Potrero de Padilla; contains tongues of limestone and dolomite that feather out southward and thicken northward; no volcanic material present	410
Menchaca limestone	
2. Limestone, dark blue-black; beds average about 18 inches in thickness; contains *Exogyra reedi* Imlay and *E. putnami* Imlay	1,743
Unnamed shale	
1. Shale, partly sandy, brown and gray, with intercalated beds of brownish gray limestone ranging from a few inches to several feet in thickness; weathers brownish yellow; marly bed at base contains *Exogyra reedi* Imlay, *E. putnami* Imlay and *Vermetus carnejoi* Castillo and Aguilera, according to Wm. G. Kane; however, a Jurassic age for the shale is possible	557
Total thickness	8,996±

The ages of the beds in these sections are determined (1) by the presence of the upper Aptian ammonite *Dufrenoya texana* Burckhardt at the base of the Aurora limestone and (2) by the occurrence of lower Hauterivian ammonites in the Barril Viejo shale. Correlation of the Barril Viejo shale with the upper member of the Taraises formation on the central part of the Mexican geosyncline is shown by the presence of *Acanthodiscus magnificus* Imlay, *A.* cf. *A. radiatus* Bruguière, *Leopoldia victoriensis* Imlay, and *L.* cf. *L. bakeri* Imlay.[350] The Menchaca limestone and the underlying shales at Potrero de Menchaca contain *Exogyra reedi* Imlay and *E. putnami* Imlay that are common in beds of Valanginian age near Miquihuana, Tamaulipas. On the basis of stratigraphic position, the Padilla limestone is probably equivalent to the Cupido limestone of the central part of

[349] R. W. Imlay, *op. cit.* (1940a), pp. 121, 122.

[350] R. W. Imlay, *op. cit.* (1940a), pp. 132, 133.

the Mexican geosyncline. The Patula arkose, the Cuchillo formation in part, and the marly beds at the base of the Aurora limestone are probably equivalent to the La Peña formation. The Aurora limestone contains many caprinids and is similar to the same formation in the Sierra de Parras. On the west side of the Sierras de Bustamante and Azul, near Monclova, it is overlain by thin-bedded, gray limestone containing lenses of black chert that corresponds with the Cuesta del Cura limestone.[351] The occurrence of Upper Cretaceous beds in the synclinal valleys of eastern Coahuila has been indicated by Böse and Cavins,[352] but few sections have been described. At the eastern base of the Sierra de Azul the Turonian beds are about 1,070 feet thick.[353] They are overlain in the region between Cuatro Ciénegas and Monclova by shaly limestone and marl equivalent to the Austin chalk of Texas. Then follows shale equivalent to the Taylor marl of Texas. On the Mesa de Cartujanos east of Sierra de Azul[354] are exposed about 820 feet of shale and sandy limestone containing *Exogyra costata* Say and *Sphenodiscus lenticularis* Owen. Above follows about 460 feet of sandstone, sandy shale, and conglomerate containing shark teeth, oysters, and plant remains. These beds are discussed in more detail in considering the stratigraphy of northern Nuevo León and Coahuila.

NORTHERN NUEVO LEÓN AND ADJOINING PARTS OF TAMAULIPAS AND COAHUILA

A fairly complete Cretaceous section was penetrated by the Mexican Gulf Oil Company's San Ambrosio well No. 1, about 52 kilometers S. 45° W. of Laredo, Texas (Fig. 12). It may be described, from top to bottom, as follows.

	Depth in Feet	*Thickness in Feet*
San Miguel formation	0–370	370
Papagallos formation	3,010	2,640
San Felipe formation	3,610	600
Agua Nueva formation	4,060	450
Buda limestone	4,160	100
Del Rio formation		
Shale and limestone, gray to black	4,230	70
Georgetown-Edwards limestone		
Hard, dense, dark to light gray	5,190	960
Glen Rose equivalents and older beds		
Shale, calcareous, black, interbedded with brittle limestone; core from depth of 5,646–5,651 feet contained *Parahoplites*, according to Burckhardt	6,000	810
Limestone, hard, dense, brittle, dark gray	6,390	390
Shale, calcareous, black, thinly laminated, interbedded with light to dark limestone; lower 410 feet very carbonaceous	7,600	1,210
Shale, calcareous, black, and some dark gray, marly limestone; shalier than overlying unit; cores between depths of 7,997–8,012 feet contained *Bochianites*, *Hoplites?*, and *Crioceras*, according to Burckhardt	8,360	760
Limestone, hard, brittle, black; has angular fracture, finely disseminated pyrite crystals and mica flakes; black, calcareous shale in lower part; same microfauna as above unit; overlies Upper Jurassic shale	8,360	240
	8,600	8,600

[351] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), p. 24.

Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 176.

[352] Emil Böse and O. A. Cavins, *op. cit.* (1927), pl. 19, p. 31.

[353] *Ibid.*, pp. 30, 32.

[354] Carlos Burckhardt, *op. cit.* (1930), p. 248.

The lowermost 240 feet of hard limestone is similar lithologically to the lower member of the Taraises formation of the Mexican geosyncline. The overlying 760 feet is similar to the upper member of the Taraises formation and contains ammonites indicating an age not younger than Hauterivian. On the basis of stratigraphic position the writer would provisionally assign the overlying 1,310 feet of interbedded shale and limestone to the Barremian, and the 390 feet of hard limestone to the lower Aptian. The 810 feet of interbedded shale and limestone immediately below the Edwards limestone probably corresponds with both the Glen Rose limestone and the Travis Peak formation of the outcrop in central Texas. The *Parahoplites* obtained near the middle of the 810 feet might be either of lower Albian or upper Aptian age. The identifications of the overlying formations are based on lithologic comparisons with the rocks exposed in northern Nuevo León and are probably correct.

In the Sierra de Lampazos (Fig. 11), according to Böse and Cavins,[355] the Comanche section, from top to bottom, follows.

	Thickness in Feet
3. Limestone, thin-bedded, alternating with marl, gray; contains *Pervinquieria*	492
2. Marl and thin-bedded limestone, reddish gray; contains *Oxytropidoceras*, *Turrilites* aff. *T. bergeri* Brongniart, and *Macraster*	328
1. Limestone, thick-bedded, hard, gray to black, contains nodules of black chert; contains *Hoplites* aff. *H. rudis* Parona and Bonarelli; does not contain rudistids	1,640—
	2,460

The lowermost unit must be of middle and perhaps of lower Albian age. It differs from the Aurora limestone exposed a little farther west in the Sierras de Bustamante and Azul by lacking rudistids. The middle unit contains *Oxytropidoceras* related to *O. acutocarinatum* (Shumard) and *O. belknapi* (Marcou) and occupies the same stratigraphic position as the Kiamichi formation of Texas. The upper unit containing *Pervinquieria* is of upper Albian age, but it may include some of the Cenomanian. Böse and Cavins[356] consider that the middle and upper units pass westward in the Sierras de Bustamante and Azul into thin-bedded limestone containing many beds of black chert to which the same Cuesta del Cura limestone is applied.

The Turonian, according to Böse and Cavins,[357] consists of black, thinly laminated limestone and black shale that is more shaly at some places than at others and contains *Inoceramus labiatus* (Schlotheim) and *I. hercynicus* Petrascheck. It has been observed in Nuevo León along the flanks of the Sierras de Lampazos, Minas Viejas, and Vallecillo, on the western flank of the Sierra de Bustamante, and near Ramones on the eastern slope of the Sierra de Papagayos about 43 miles east of Monterrey. In northeastern Coahuila it has been observed in the Lomas

[355] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), pp. 23, 24.

[356] Emil Böse and O. A. Cavins, *op. cit.* (1927), p. 24.

[357] *Ibid.*, pp. 30, 31.

de Peyote, south of Ojo de Agua near Encinas, and along the eastern base of the Sierra de Azul, where it is slightly more than 1,000 feet thick.

The Coniacian and Santonian stages, or the equivalents of the Austin chalk of Texas, are represented by two facies. In eastern Nuevo León and northern Tamaulipas they are included in the lower part of the Papagayos shale.[358] In northwestern Nuevo León and in northeastern Coahuila in the area of the Río Salado and Río Sabinas,[359] they are represented by gray to white marl and chalky limestone about 1,300 feet thick that Dumble[360] named the San Juan limestone but which may satisfactorily be called the Austin chalk. The lower three-fourths of the formation has furnished giant Inocerami related to *Inoceramus undulatoplicatus* Roemer. The upper fourth has furnished *Texanites texanum* (Roemer), *Canadoceras flaccidicostum* (Roemer), *Baculites*, and large *Inoceramus*.

Beds equivalent to the Taylor marl of Texas consist of shale and were at one time called Papagayos but are now called Méndez shale. Böse and Cavins[361] considered the shale to be upper Santonian in age, but Stephenson[362] has shown that the Taylor marl is of Campanian age. In the area of the Río Salado and Río Sabinas the Méndez (Papagayos) shale consists of about 985 feet of dark gray shale alternating basally with thin beds of gray limestone. Farther east the limestone beds are absent. Fossils are abundant and include such forms as *Exogyra ponderosa* Roemer and *Placenticeras syrtale* Morton.

Beds of Navarro age in northern Nuevo León and northeastern Coahuila attain considerable thicknesses, consist mainly of sandstone and shale but include some marl, limestone, and coal, and were deposited under marine, brackish, and continental environments. They have been observed at many localities by various workers,[363] whose writings have been summarized by Burckhardt,[364] but

[358] Emil Böse and O. A. Cavins, *op. cit.* (1927), pp. 68, 69.
Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 227.

[359] Emil Böse and O. A. Cavins, *op. cit.* (1927), pp. 31–34.
Carlos Burckhardt, *op. cit.* (1930), p. 226.

[360] E. T. Dumble, "Tertiary Deposits of Northeastern Mexico," *Proc. California Acad. Sci.*, Vol. 5, No. 6 (1915), p. 170.

[361] Emil Böse and O. A. Cavins, *op. cit.* (1927), pp. 34–37.

[362] L. W. Stephenson, "The Larger Invertebrate Fossils of the Navarro Group of Texas," *Univ. Texas Bull. 4101* (1941), pp. 34, 35.

[363] R. A. Jones, "A Reconnaissance Study of the Salado Arch, Nuevo León and Tamaulipas, Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 9 (1925), pp. 123–33; 1 fig.
Emil Böse and O. A. Cavins, *op. cit.* (1927), pp. 37–56, 101–07.
C. A. White, "Late Observations Concerning the Molluscan Fauna and the Geographical Extent of the Laramie Group," *Amer. Jour. Sci.*, 3d Ser., Vol. 25 (1883), p. 207.
———, "Correlation Papers. Cretaceous," *U. S. Geol. Survey Bull. 82* (1891), pp. 130–40.
Emil Böse, "Vestiges of an Ancient Continent in Northeast Mexico," *Amer. Jour. Sci.*, 5th Ser., Vol. 6 (1923b), p. 334.
F. K. G. Mullerried, "Informe preliminar acerca de la geología y zonas petrolíferas de una parte de la región carbonifera de Coahuila y Nuevo León," *Foll. Divulgación, Inst. Geol. México*, No. 26 (1927), p. 11.
Manuel Schwartz, "Le charbon au Mexique," *Soc. Cient. "Antonio Alzate," Mem. y Rev.*, T. 32 (1912), pp. 1–23, map.

very little detailed stratigraphic work has been done. Böse and Cavins have made the largest number of observations for the area as a whole and have presented a picture of stratigraphic changes from northwest to southeast that is at variance with observations of earlier workers. Their ideas of the stratigraphic succession, from top to bottom, have been summarized by Burckhardt[365] about as follows.

Northwest	*Southeast*
Eagle Pass to Las Esperanzas	Lampazos to Saltillo
Escondido formation with *Sphenodiscus*	Escondido formation with *Sphenodiscus*
Coal beds (Olmos formation)	Marine beds with *Exogyra costata* Say
San Miguel formation with *Exogyra costata* Say	Tulillo brackish-water beds

Burckhardt[366] noted that the views of Böse and Cavins did not harmonize with those of previous workers in Mexico or Texas, and that they involved rather complicated advances and retreats of the sea. The fact that the Tulillo brackish-water beds extending from El Pescado south-southwest to Saltillo are paralleled on the northwest by the Olmos coal beds, extending from Piedras Negras to Monclova, indicated to Burckhardt that the two facies were formed during a single retreatal phase of the sea. Accordingly, Burckhardt[367] proposed a stratigraphic succession from top to bottom about as follows:

Northwest	*Southeast*
Escondido formation	Continental deposits
Olmos formation	Tulillo brackish-water beds
San Miguel formation	Beds with *Exogyra costata* Say and *Sphenodiscus*

The foregoing correlation can not be maintained because Stephenson[368] has shown that the San Miguel formation is of upper Taylor age, that it does not contain the typical form of *Exogyra costata* Say, and that an important faunal break between the San Miguel and Escondido formations is only partly filled by the coal beds of the Olmos formation. The existence of the Tulillo beds as a definite unit over a large area may be questioned, considering that they are only about 330 feet thick,[369] have furnished brackish-water faunas at only two locali-

T. W. Vaughan, "Reconnaissance in the Rio Grande Coal Fields of Texas," *U. S. Geol. Survey Bull. 164* (1900). 88 pp., maps.

Edwin Ludlow, "Les gisements carboniferes de Coahuila," *International Geol. Congress X, Mexico, Guide Excursion 28* (1906). 17 pp.

E. T. Dumble, "Notes on the Geology of the Middle Rio Grande," *Bull. Geol. Soc. America*, Vol. 3 (1892), pp. 219–30.

J. G. Aguilera, "Les gisements carboniferes de Coahuila," *International Geol. Congress X, Mexico, Guide Excursion 27* (1906b). 17 pp., map.

364 Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 244–50, 252–58.

365 Carlos Burckhardt, *op. cit.* (1930), p. 246.

366 *Ibid.*, pp. 246, 247.

367 *Ibid.*, p. 248.

368 L. W. Stephenson, "Taylor Age of San Miguel Formation of Maverick County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15 (1931), pp. 793–800.

369 Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), pp. 37–40.

ties, have not actually been traced along the outcrop, and that brackish-water fossils might be expected to occur at various levels in the thick sequence of sandstone and shale comprising the latest Cretaceous of northwestern Nuevo León and northeastern Coahuila. No detailed correlation of these beds is possible until additional field studies are made, particularly of the excellently exposed sections in the Mesa de Guajardo west of Saltillo and in the Mesa de Cartujanos west of Lampazos.

AREA BETWEEN SIERRA DEL BURRO AND RÍO GRANDE

Beds ranging in age from Aptian to Maestrichtian drop out in the Sierra del Burro (Fig. 11) or along its northern and eastern flanks.[370] The section is similar to that in adjoining parts of Texas but more calcareous. It may be summarized, from top to bottom, as follows.

	Thickness in Feet
Escondido formation	
Sandstone, sandy shale, shale, conglomerate, and sandy limestone of various colors; sandstones locally cross-bedded, or ripple marked, and commonly glauconitic; characterized by *Exogyra costata* Say and *Sphenodiscus;* overlain disconformably by Midway formation	750+
Olmos formation	
Clay, shale, sandstone, and coal; does not contain marine fossils; disconformities probable at top and bottom	885±
San Miguel formation	
Sandstone, sandy shale, shale, sandy to shaly limestone, generally gray, hard to soft, characterized by *Exogyra ponderosa* Roemer and *E. costata spinifera* Stephenson	400±
Upson clay	
Clay, greenish gray to dark gray; weathers yellowish; contains *Exogyra ponderosa* Roemer	700±
Austin chalk	
Limestone, shaly, gray, characterized by *Texanites texanus* (Roemer) and *Canadoceras flaccidicostum* (Roemer)	330
Limestone, chalky, white, characterized by *Peroniceras* and *Gauthiericeras* cf. *G. margae* (Schlüter)	985
Limestone, shaly to marly, black to white, characterized by *Barroisiceras* aff. *B. haberfellneri* (Hauer)	

[370] E. T. Dumble, "Tertiary Deposits of Northeastern Mexico," *Proc. California Acad. Sci.*, Vol. 5, No. 6 (1915), pp. 163–93, Pls. 16–19.

L. W. Stephenson, "The Cretaceous-Eocene Contact in the Atlantic and Gulf Coastal Plain," *U. S. Geol. Survey Prof. Paper 90* (1915), pp. 169–76. "Taylor Age of San Miguel Formation of Maverick County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15 (1931), pp. 793–800; 1 fig.

Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), pp. 19, 23, 24, 26–28, 31–33, 35, 37, 44–46, 83, 85, 89–91, 94.

Jorge Cumming, "Informe preliminar acerca del reconocimiento geológico-petrolero, de la parte norte del estado de Coahuila," *Foll. Divulgación, Inst. Geol. México*, No. 29 (1928). 29 pp., map.

Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 147, 188–90, 218, 219, 225, 226, 255–57.

J. L. Tatum, "General Geology of Northeast Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15 (1931), pp. 872–77.

W. S. Adkins, "The Mesozoic Systems in Texas" in "The Geology of Texas," Vol. 1, Stratigraphy, *Univ. Texas Bull. 3232*, Pt. 2 (1933), pp. 298, 392, 427.

Wm. G. Kane and G. B. Gierhart, "Areal Geology of Eocene in Northeastern Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19 (1935), pp. 1360–64.

Carlos Burckhardt and F. K. G. Mullerried, "Neue Funde in Jura und Kreide Ost- und Sud-Mexicos," *Eclogae geol. Helvetiae*, Vol. 29, No. 2 (1936), pp. 320, 321.

R. W. Imlay, "Ammonites of the Taraises Formation of Northern Mexico," *Bull. Geol. Soc. America*, Vol. 49 (1938a), p. 546.

	Thickness in Feet
Eagle Ford formation (Boquillas facies)	
Limestone, thin-bedded, thinly laminated, black; alternating with black shale; locally sandy and gypsiferous; contains *Inoceramus labiatus* (Schlotheim) and *I. hercynicus* Petrascheck; upper part near Villa Acuna consists of white marl and limestone and contains *Prionotropis woolgari* var. *mexicana* Böse; contact with underlying Buda limestone marked by pockets of yellowish sand overlain by about ½ foot of sandy limestone	650–920
Buda limestone	
Limestone, brittle, gray to white, interbedded with a few thin, marly layers; contains *Budaiceras*, *Mantelliceras*, *Sharpeiceras*, and *Euhystrichoceras*	80±
Del Río clay	
Marl and clay, gray; upper part has beds of sandy limestone and some gypsum; passes southward into hard, thin-bedded limestone similar to Buda limestone; characterized by *Exogyra arietina* Roemer, *Stoliczkaia*, *Submantelliceras*, and *Adkinsia*	0–225
Georgetown limestone	
Limestone, thin-bedded, and marl, white to gray; at top contains *Turrilites brazoensis* Roemer; *Pervinquieria* characteristic	
Kiamichi formation (?)	
Limestone, shaly, dark; weathers light gray; some dolomitic lenses	1,200 (Georgetown, Kiamichi and Edwards)
Edwards limestone	
Limestone, thick-bedded, compact; some dark brown chert intercalations; contains caprinids and radiolitids	
Comanche Peak formation	
Marl, greenish gray; contains calcareous concretions and many *Exogyra texana* Roemer	50
Glen Rose limestone	
Limestone, hard beds alternating with marly beds; contains *Douvilléiceras?* near base	2,000+
Unnamed shaly limestone and shale containing many *Cheloniceras* and *Toxaster*	?

Sediments of Neocomian age may exist in northern Coahuila. The Ohio-Mexican Oil Company's Zambrano well No. 1, about 45 miles northwest of Del Río, Texas, started at the top of the Georgetown limestone and penetrated arkose from 3,200 to 4,500 feet. The Ohio-Mexican Oil Company's Trevino well No. 1, about 23 miles southwest of Del Río, penetrated arkose from depths of 3,250 to 4,800 feet.

SIERRA DEL CARMEN AREA OF NORTHWESTERN COAHUILA

Upper Aptian shaly limestone and shale containing *Cheloniceras* rest on unfossiliferous red shale near La Babia in the Sierra del Agua de las Cabras, a branch of the Sierra del Carmen.[371] Farther west in the same range, south of Boquillas, the Aptian is reported to rest directly on mica-schist.[372] Above the Aptian shaly beds are about 1,640 feet of gray, massive limestone representing the Albian. These are overlain near Boquillas by platy limestone and shale containing *Inoceramus labiatus* (Schlotheim). Light gray to white, chalky limestone, marl, and marly limestone containing *Inoceramus undulatoplicatus* Roemer have been observed near Rancho del Jardin in the Sierra del Carmen and at Tinaja del Panal between Boquillas and San Vicente. These beds are overlain near Rancho del Centinela by gray shale and marl containing *Exogyra ponderosa* Roemer, and at Tinaja del Panal by shale and calcareous sandstone containing *Exogyra ponderosa* Roemer and *Placenticeras planum* Hyatt.[373]

[371] Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), p. 19.

[372] C. L. Baker in Emil Böse, "Vestiges of an Ancient Continent in Northeast Mexico," *Amer. Jour. Sci.*, 5th Ser., Vol. 6 (1923b), p. 133.

[373] Jorge Cumming, "Informe preliminar acerca del reconocimiento geológico-petrolero, de la parte norte del estado de Coahuila," *Foll. Divulgación, Inst. Geol. México*, No. 29 (1928), p. 29.

SANTA EULALIA AND SAN PEDRO CONCHOS, CENTRAL CHIHUAHUA

In a gorge cut by the Río San Pedro across the Sierra de Villalba, south of San Pedro Conchos, the following section was observed by Paul Waitz.[374]

	Thickness in Feet
5. Marls, generally dark-colored, bluish, greenish, and yellowish; contain many intercalations of sandstone; thickness considerable	?
4. Limestone, medium-bedded, gray; lower part contains nodules of black chert; upper part contains *Gryphaea "pitcheri"* Morton, *Trigonia*, other bivalves, and gastropods	164
3. Marl, yellowish	66±
2. Limestone, thick-bedded, gray	197±
1. Limestone with intercalations of marl	?

It seems likely that units 1–4 are of Washita age and unit 5 is of early Upper Cretaceous age.

In the Sierra de Santa Eulalia, situated about 12 miles east-southeast of the City of Chihuahua, are exposed from 1,970 to 2,950 feet of dark gray, compact, massive limestone containing nodules of chert. The presence of *Toucasia* and other rudistids has indicated correlation with the Edwards limestone of Texas.[375] Above follow shaly marls reported[376] to be Upper Cretaceous in age and to rest unconformably on the Lower Cretaceous limestone.

RÍO CONCHOS AREA OF EASTERN CHIHUAHUA

The geology of the lower 60 miles of the valley of the Río Conchos between Aldama and Ojinaga (Fig. 8) has been discussed by many geologists.[377] The Cuchillo Parado and Placer de Guadalupe districts were mapped in reconnaissance by R. E. King and W. S. Adkins in 1933, but their report has not been published. Detailed stratigraphic studies of the area have not yet been made.

[374] Paul Waitz, "Informe sobre las condiciones geológicas de las boquillas del Río de San Pedro, afluente del Río Conchos, Chihuahua," *Soc. cient. "Antonio Alzate" Mem. y Rev.*, T. 49 (1928), pp. 246, 247.
Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), p. 186.

[375] Carlos Burckhardt, *op. cit.* (1930), p. 187.

[376] Trinidad Paredes, "Apuntes sobre algunos minerales del Estado de Chihuahua," *Bol. Soc. Geol. Mexicana*, T. 8 (1912), p. 23.

[377] J. P. Kimball, "Notes on the Geology of Western Texas and of Chihuahua, Mexico," *Amer. Jour. Sci.*, 2d Ser., Vol. 48 (1869), pp. 378–88.
W. H. Weed, "Notes on a Section across the Sierra Madre Occidental of Chihuahua and Sinaloa, Mexico," *Trans. Amer. Inst. Min. Eng.*, Vol. 32 (1902), pp. 444–58, sections.
R. T. Hill, "The Santa Eulalia District, Mexico," *Eng. and Min. Jour.*, Vol. 76 (1903), pp. 158–60.
R. H. Burrows, "Geology of Northern Mexico," *Bol. Soc. Geol. Mexicana*, T. 7 (1910), pp. 85–103, map.
Emil Böse, "Monografia geológica y paleontólogica del Cerro de Muleros cerca de Ciudad Juarez y descripción de la fauna cretácea de la Encantada, Placer de Guadalupe, Estado de Chihuahua," *Bol. Inst. Geol. México*, Núm. 25 (1910b). 193 pp., illus., map.
Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), pp. 22, 25, 28, 35, 68, 83, 86, 95, 98, 99, 103, 171–74.
Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 147, 179, 187, 218, 239.
W. S. Adkins, "The Mesozoic Systems in Texas" in "The Geology of Texas," Vol. 1, Stratigraphy, *Univ. Texas Bull. 3232*, Pt. 2 (1933), pp. 291–95, 427.

A section observed by Böse and Cavins[378] about 4 kilometers south of Ojinaga, from top to bottom, follows.

4. Shale, sandstone, and conglomerate
3. Shale, very sandy, light gray, and many beds of limestone; contains *Placenticeras sancarlosense* Hyatt, *P. planum* Hyatt, *P. guadalupae* (Roemer), *P. newberryi* Hyatt, *P.* aff. *P. syrtale* (Morton), *Exogyra* aff. *E. ponderosa* Roemer, *Inoceramus cumminsi* Cragin
2. Shale and marl, sandy, gray to yellow; some layers of limestone; contains *Texanites texanus* (Roemer)
1. Sandstone, reddish, and sandy shale with concretions of sandy limestone containing *Peroniceras* aff. *P. subtricarinatum* D'Orbigny and *Proplacenticeras* aff. *P. fritschi* Grossouvre

Beds of coal associated with sand and shale occur near Ojinaga and to the south-southeast in the Sierra Rica. Burckhardt[379] considers that the coal is of the same age as that near San Carlos in Presidio County, Texas, which Stanton[380] considers of Taylor age. In the section near Ojinaga, units 1 and 2 are correlated with the Austin chalk, unit 3 with the Taylor marl, and unit 4 possibly with the Navarro. Perhaps unit 4 is identical with the Tornillo formation which Adkins[381] says crops out south and west of Ojinaga. Beneath the reddish sandstone of Austin age occur bituminous shale and limestone containing *Inoceramus labiatus* (Schlotheim) and *I. hercynicus* Petrascheck[382] that has been called the Ojinaga formation. It is the same shale facies that Adkins[383] named the Chispa Summit formation on the basis of exposures in western Jeff Davis County, Texas. These Upper Cretaceous beds have not been measured, but Stanton[384] estimated that the part older than Taylor is 3,000 to 4,000 feet thick.

Between Cuchillo Parado and Aldama no Cretaceous rocks younger than Turonian have been observed. The section, from top to bottom, may be summarized as follows.[385]

	Thickness in Feet
Ojinaga formation	
Shale and limestone, some sandstone; contains *Inoceramus labiatus* (Schlotheim), *Romaniceras, Prionotropis, Prohauericeras, Coilopoceras*	700?
Buda limestone	
Limestone, hard, nodular, cream-colored; contains *Budaiceras;* disconformity noted at top	?
Del Río shale	
Shale, soft, green, with sandy nodules, contains *Exogyra arietina* Roemer	?

378 Emil Böse and O. A. Cavins, *op. cit.* (1927), pp. 35, 68, 95, 98, 99, 103.
Carlos Burckhardt, *op. cit.* (1930), p. 239.

379 Carlos Burckhardt, *op. cit.* (1930), p. 239.

380 T. W. Vaughan, "Reconnaissance in the Rio Grande Coal Fields of Texas," *U. S. Geol. Survey Bull. 164* (1900), p. 82.

381 W. S. Adkins, *op. cit.* (1933), p. 509.

382 Emil Böse, "Algunas faunas cretácicas de Zacaticas, Durango y Guerrero," *Bol. Inst. Geol. México*, Núm. 42 (1923a), p. 45.
Gonzalo Vivar, "Informe preliminar sobre el estudio geológico-petrolero de la región de Ojinaga, Estado de Chihuahua, Mexico," *Departmento de Exploraciónes y Estudios Geológicos, Folleto de Divulgación*, No. 16 (1925), p. 6.

383 W. S. Adkins, *op. cit.* (1933), pp. 426, 437.

384 T. W. Vaughan, *op. cit.* (1900), p. 82.

385 Carlos Burckhardt, *op. cit.* (1930), pp. 148, 187.

	Thickness in Feet
Aurora limestone	
Limestone, thick-bedded, massive, gray; some chert nodules; contains rudistids; thickens westward. At La Encantada thin marly unit contains *Oxytropidoceras*, *Exogyra texana* Roemer, and *Gryphaea navia* Hall	590–1,475
Glen Rose limestone	
Limestone, thin- to medium-bedded, black, alternating with shale; contains *Orbitolina texana* Roemer and caprinids	?
Cuchillo formation	
Shales and shaly limestone, some sandstone; contains *Dufrenoya*, *Cheloniceras*, *Hypacanthoplites*, *Exogyra quitmanensis* Cragin, *Trigonia* aff. *T. taffi* Cragin	500
Gypsum, white, and shale; rock salt near base	1,500
Las Vigas formation	
Sandstone, gray to reddish, in thin beds alternating with shale; beds of gypsum and limestone near top; contains small *Exogyra* and plant remains	750
Shale, black, gray, red	240
Sandstone, calcareous, gray to reddish	700
Limestone, sandy	250

The Las Vigas formation has not furnished determinable fossils and may represent part or all of the Neocomian. Its contact with the underlying late Jurassic La Casita formation has not been described. The Cuchillo formation contains many upper Aptian fossils near its top, so the mass of gypsum and rock salt is probably lower Aptian in age. Burrows[386] completely overlooked the *Orbitolina*-bearing beds at the base of the thick-bedded limestones that he called Aurora limestone. The Aurora limestone is a rudistid-bearing limestone probably identical lithologically with the Devils River limestone of Val Verde County, Texas, and equivalent to beds of Georgetown and Fredericksburg age. On the Sierra de la Encantada, 5 miles west-northwest of Placer de Guadalupe, about 16 feet of red marl and marly limestone, underlying a considerable thickness of rudistid limestone, has furnished a large fauna[387] that is of middle Albian age, probably equivalent to the Kiamichi formation of Texas. On the Cuesta del Alamo, about 10 miles northeast of Cuchillo Parado, the upper part of the Aurora limestone has furnished *Ostrea* (*Lopha*) *carinata* Lamarck, *Enallaster* cf. *E. bravoensis* Böse, and *Enallaster* cf. *E. texanus* Roemer. The first two species suggest a Washita age. The Del Río and Buda formations appear to be typically developed. The Ojinaga formation contains a large fauna of upper Turonian age.

CERRO MULEROS IN NORTHERN CHIHUAHUA

The section on Cerro Muleros (Fig. 8) west of El Paso, Texas,[388] may be summarized, from top to bottom, as follows.

[386] R. H. Burrows, "Geology of Northern Mexico," *Bol. Soc. Geol. Mexicana*, T. 7, (1910), pp. 85–103, map.

[387] Emil Böse, "Monografia geológica y paleontólogica del Cerro del Muleros cerca de Ciudad Juarez y descripción de la fauna cretácea de la Encantada, Placer de Guadalupe, Estado de Chihuahua," *Bol. Inst. Geol. México*, Núm. 25 (1910b), pp. 52, 53.

[388] T. W. Stanton and T. W. Vaughan, "Section of the Cretaceous at El Paso, Texas," *Amer. Jour. Sci.*, 4th Ser., Vol. 1 (1896), pp. 21–26.
Emil Böse, *op. cit.* (1910b), pp. 52, 53.
Emil Böse and O. A. Cavins, "The Cretaceous and Tertiary of Southern Texas and Northern Mexico," *Univ. Texas Bull. 2748* (1927), pp. 149, 152.
Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 179–85, 218.
W. S. Adkins, "The Mesozoic Systems in Texas" in "The Geology of Texas," Vol. 1, Stratigraphy, *Univ. Texas Bull. 3232*, Pt. 2 (1933), pp. 339, 355, 362, 368, 369, 373, 380, 382, 385, 393, 399, 431.

	Thickness in Feet
Eagle Ford formation (or Colorado shale)	
Shale, sandy limestone, and fine-grained sandstone, brown to dark gray; contains *Inoceramus labiatus* (Schlotheim)	350
Woodbine formation (or Dakota sandstone)	
Sandstone, fine-grained, hard, poorly stratified, yellow to nearly white; grades at base into yellowish gray shale	820
Buda limestone	
Limestone, fairly thick-bedded, hard, light yellowish gray; contains *Exogyra clarki* Shattuck, *Protocardia* sp., *Enallaster bravoensis* (Böse), and *Turritella* sp.	35– 75
Del Rio shale	
Marl, shaly and marly limestone; some clay partings, yellowish gray; contains *Exogyra whitneyi* Böse, *Hemiaster calvini* Clark, *Enallaster bravoensis* (Böse), *Neithea subalpina* (Böse)	35– 75
Main Street equivalent	
Sandstone, quartzitic, hard, coarse to medium-grained, fairly thick-bedded, red to brown; some beds whitish to yellowish; some thin shaly layers in upper part contain *Exogyra arietina* Roemer, *Exogyra whitneyi* Böse, and *Hemiaster calvini* Clark	75–330
Pawpaw-Weno equivalents	
Shale alternating with brown, flaggy sandstone; contains *Lopha quadriplicata* (Shumard) *Gryphaea washitaensis* Hill, *Lopha subovata* Shumard; black shale near base contains *Neokentroceras* and *Pervinquieria*	35– 75
Denton-Fort Worth equivalents	
Marl and beds of soft, nodular limestone; some shale partings; sandy beds at base; contains *Pervinquieria trinodosum* (Böse), *Leonites nodosum* (Böse), *Prohysteroceras burckhardti* (Böse), *Gryphaea washitaensis* Hill, many pelecypods and gastropods; many echinoids in upper part	100–165
Duck Creek equivalent	
Shale, mainly dark gray to black, some marl, limestone, and thin lentils of gypsum; contains *Prohysteroceras whitei* (Böse), *Leonites nodosum* (Böse), *Pervinquieria trinodosum* (Böse)	100–165
Kiamichi formation	
Limestone, partly sandy, brown to gray; some gray sandstone, brown to yellow marl, and black shale; contains *Oxytropidoceras* (*Adkinsites*) cf. *O. belknapi* (Marcou), *Gryphaea navia* Hall, *Exogyra texana* Roemer, *Gryphaea tucumcarii* Marcou	30
Marl, shaly to sandy, yellowish brown; some beds of sandstone and limestone; contains *Oxytropidoceras* aff. *O. acuticarinatum* (Shumard), *O. bravoensis* (Böse), *O.* cf. *O. belknapi* (Marcou), *Gryphaea navia* Hall, *G. tucumcarii* Marcou, *Exogyra texana* Roemer	35– 75
Edwards limestone (Finlay limestone)	
Limestone, thick-bedded, hard, gray; some beds shaly; contains *Gryphaea navia* Hall, *G. tucumcarii* Marcou, *Exogyra texana* Roemer, *Toucasia* cf. *T. texana* (Roemer)	75– 80
Unnamed sandstone	?

ARIVECHI AREA OF EASTERN SONORA

The section near Arivechi, east of the valley of Sahuaripa, Sonora, has been described by King[389] and may be summarized, from top to bottom, as follows.

	Thickness in Feet
"Potrero" formation	
Shale, marl, and thin-bedded sandy limestone, some interbedded andesite and agglomerate; contains *Engonoceras gabbi* Boehm, *Exogyra texana* Roemer, *Gryphaea mucronata* Gabb, *Lunatia? pedernalis* (Roemer), and many other fossils of Fredericksburg age	5,200
Palmar formation	
Limestone mainly, interbedded with shale and quartzite in upper 125 feet and with shale and sandstone in next lower 2,300 feet; coarse conglomerate 1,000 feet thick at base; lower third contains *Phylloceras* of Albian type	4,550

[389] R. E. King, "Geological Reconnaissance in Northern Sierra Madre Occidental of Mexico," *Bull. Geol. Soc. America*, Vol. 50 (1939), pp. 1660–73.

The Potrero formation is definitely Fredericksburg in age,[390] and the Palmar formation is probably Trinity in age. King[391] shows that west of Arivechi, between the Río de Sahuaripa and the Río Yaqui, the Cretaceous changes mainly to a clastic and volcanic facies consisting of quartzitic sandstone, agglomerate, andesite flows, and in some places a basal limestone unit. West of the Río Yaqui the Cretaceous consists dominantly of lava that overlies continental beds of latest Triassic and possibly early Jurassic age. The name "Potrero" was first employed by Böse[392] for lower Jurassic marine shale in the Huasteca region of Veracruz and Puebla.

EL TIGRE AREA OF NORTHEASTERN SONORA

The Cretaceous section at the head of Cañon de Santa Rosa, near El Tigre, in the Sierra de Teras (El Tigre) has been described by the writer.[393] It consists of 2,845 feet of alternating units of limestone, sandstone, and shale, is conglomeratic in its basal 46 feet, and rests on Permian limestone. *Exogyra quitmanensis* Cragin occurs throughout most of the section and is evidence of its Trinity age. About 565 feet above the base is a thick unit of shale that has furnished *Parahoplites* cf. *P. uhligi* Anthula, *Beudanticeras, Acanthoplites, Cheloniceras* cf. *C. cornueli* (D'Orbigny), *Exogyra quitmanensis* Cragin, *Cucullaea, Plicatula,* and echinoids. These forms might represent either lower Albian or upper Aptian but the latter age is favored by the presence of species similar to *Parahoplites uhligi* and *Cheloniceras cornueli* and by the absence of *Orbitolina,* which is so characteristic of beds of lower and middle Albian age in the southern United States. Likewise, the forms of *Exogyra quitmanensis* are identical with those in the upper Aptian beds of Coahuila and eastern Durango. They do not include large, flat, nearly subcircular, very weakly carinated specimens such as are common in the Glen Rose formation of southern Texas.

CABULLONA AND ADJOINING AREAS OF NORTHEASTERN SONORA

The Cabullona area was studied briefly by Dumble,[394] mapped by Taliaferro,[395] and observed in reconnaissance by the writer.[396] Burckhardt[397] abstracted the descriptions of the sections measured by Dumble. King[398] compared the sections

[390] W. N. Gabb, "Notes on Some Mexican Cretaceous Fossils, with Descriptions of New Species," *Paleon. California*, Vol. 2, *California Geol. Survey* (1869), pp. 257–76.
Carlos Burckhardt, *op. cit.* (1930), pp. 176, 177.

[391] R. E. King, *op. cit.* (1939), pp. 1673–76.

[392] Emil Böse, Über Lias in Mexico," *Zeitschr. Deutsche geolog. Gesell.*, Vol. 50 (1898), p. 175.

[393] R. W. Imlay, "Paleogeographic Studies in Northeastern Sonora," *Bull. Geol. Soc. America*, Vol. 50 (1939b), pp. 1733–35.

[394] E. T. Dumble, "Notes on the Geology of Sonora," *Trans. Amer. Inst. Min. Eng.*, Vol. 29 (1900), pp. 135–37.

[395] N. L. Taliaferro, "An Occurrence of Upper Cretaceous Sediments in Northern Sonora, Mexico," *Jour. Geol.*, Vol. 41 (1933), pp. 12–37; 6 figs., 1 pl. (geologic map).

[396] R. W. Imlay, *op. cit.* (1939b), pp. 1736–39.

[397] Carlos Burckhardt, "Étude synthétique sur le mésozoïque méxicain," *Soc. Paléon. Suisse Mém.*, Vols. 49, 50 (1930), pp. 177, 178.

[398] R. E. King, *op. cit.* (1939), pp. 1676, 1677; Pl. 5.

with those in southeastern Arizona and east-central Sonora. The section described by Taliaferro may be summarized, from top to bottom, as follows.

	Thickness in Feet
CABULLONA GROUP	
Rhyolite tuff	
Tuff, fragments as much as 6 inches in diameter, white to cream-colored, land-deposited	800−
Upper redbeds	
Sandy shales, red and green, and lenses of gray to buff, cross-bedded sandstone; at base a white sandstone contains fresh-water gastropods	2,100+
Packard shale	
Shale, dark gray to black; some thin beds of dark gray to brown shaly limestone and calcareous sandstone; many thin beds of ash and bentonite; becomes increasingly more sandy toward top; contains plant fragments and marine pelecypods	1,800–2,500
Camas sandstone	
Sandstone, thick-bedded, cross-bedded, white to brownish red, partly tuffaceous, locally conglomeratic; contains minor amounts of green to red shale that becomes more common toward top; fossils consist of fresh-water pelecypods and gastropods and many silicified tree trunks	1,220
Snake Ridge formation	
Conglomerate of limestone, sandstone, and schist pebbles; white, buff, red and green sandstone; red and green sandy shale; and carbonaceous shale; fossils consist mainly of wood fragments and fresh-water pelecypods and gastropods; one *Exogyra* present; fragments of duck-bill dinosaur about 100 feet below top	2,000+
BISBEE GROUP	
Mural limestone	
Limestone, massive, light gray to white; a few beds of sandstone or shale	400
Limestone, thin-bedded to shaly, interbedded buff sandstone and reddish brown shale	300
Morita formation	
Sandstone and sandy shale, mainly red to reddish brown, locally conglomeratic, commonly cross-bedded; a few beds of limestone conglomerate and shaly limestone	5,000−
Glance conglomerate	
Conglomerate, or breccia, of schist, granite and limestone, some blocks as much as 6 feet long; thin beds of sandstone toward top; rests on rocks ranging from Pennsylvanian to pre-Cambrian	900–2,500

The Glance, Morita, and Mural formations thicken considerably toward the south.[399] The Glance conglomerate attains a thickness of 1,500 feet in the Bisbee district, but is locally absent.[400] It is 3,000 feet thick in Snake Ridge on the north side of the Cabullona basin, and at least 5,000 feet in the Sierra de los Ajos on the south side of the basin. The thickness of the Morita formation increases from about 2,000 feet near Bisbee[401] to more than 5,000 feet in the Snake Ridge. The thickness of the Mural limestone is about 650 feet near Bisbee[402] and about 1,400 feet 28 miles to the southeast near Rancho Cabullona.[403] The Cintura formation

[399] N. L. Taliaferro, *op. cit.* (1933), pp. 19–22.
R. W. Imlay, *op. cit.* (1939b), pp. 1736, 1737.

[400] J. B. Tenney, "The Bisbee Mining District," in "Ore Deposits of the Southwest," *16th International Geol. Congress Guidebook 14* (1932), p. 46.

[401] F. L. Ransome, "The Geology and Ore Deposits of the Bisbee Quadrangle, Arizona," *U. S. Geol. Survey Prof. Paper 21* (1904), p. 64.

[402] J. B. Tenney, *op. cit.* (1932), p. 46.

[403] E. T. Dumble, *op. cit.* (1900), pp. 135, 136.

attains a thickness of at least 1,800 feet in the Bisbee district but was not recorded by Taliaferro in the Cabullona basin. It is present in the Sierra de San José about 12 miles southwest of Bisbee and in a mountain 2 miles south of Rancho Cabullona.[404] At the latter place it consists of about 1,000 feet of varicolored sandstone and shale that contains intercalations of gypsum and two beds of coal.

The Bisbee group was correlated by Stanton[405] with the Comanche series. The Mural limestone contains Trinity fossils, including *Orbitolina texana* (Roemer), *Pecten stantoni* Hill, *Trigonia stolleyi* Hill, *Cassiope branneri* (Hill) var., and *Lunatia? pedernalis* (Roemer). Fossils suggestive of a Fredericksburg age include *Sphaerucaprina* cf. *S. occidentalis* (Conrad), *Turritella* cf. *T. seriatum-granulata* Roemer, and *Actaeonella* cf. *A. dolium* (Roemer), but, as these are associated with *Orbitolina texana* (Roemer), an age younger than Trinity for any part of the Mural limestone seems unlikely. Stoyanow[406] found Trinity ammonites throughout 900 feet of beds directly below the Mural limestone in the Bisbee district. His collections include *Dufrenoya*, *Cheloniceras*, *Acanthoplites*, *Parahoplites*, and *Exogyra quitmanensis* Cragin. The presence of *Dufrenoya* shows that the Morita and the base of the Mural formations are of upper Aptian age. He does not list such ammonites as *Pseudohaploceras*, *Costidiscus*, and the Ancyloceratidae that characterize the lower Aptian of Mexico. Very likely the Glance and Morita formations were formed entirely during upper Aptian time.

The unconformity between the Bisbee and Cabullona groups is probably of considerable magnitude in-as-much as (1) the Cabullona group overlaps across the Bisbee group,[407] (2) the conglomerate of the Snake Ridge formation includes pebbles and cobbles derived from the Morita formation, and (3) the Snake Ridge formation is probably not older than late Senonian. Development of the unconformity involved the local removal of rocks of late Comanche age as shown by the occurrence of (1) *Exogyra arietina* Roemer on the summit of the next to the highest peak in the Huachuca Mountains about 20 miles southwest of Bisbee, and (2) of *Stoliczkaia*[408] in the Patagonia Mountains still farther west.

The age of the Cabullona group is probably latest Upper Cretaceous, as indicated by the presence of duck-bill dinosaur bones near the top of the Snake Ridge formation, and the fact that in North America thick conglomerate is uncommon in Upper Cretaceous beds older than Campanian. It seems most probable that the Cabullona group is entirely continental. The presence of "a badly rolled oyster and a poorly preserved *Exogyra*"[409] in the basal conglomerate of the

[404] E. T. Dumble, *op. cit.* (1900), pp. 135, 136.

[405] R. L. Ransome, *op. cit.* (1904), pp. 70, 71.

[406] A. A. Stoyanow, "Lower Cretaceous Stratigraphy in Southeastern Arizona," *Proc. Geol. Soc America, 1937* (1938), p. 117.

[407] N. L. Taliaferro, *op. cit.* (1933), p. 32.

[408] A. A. Stoyanow, *op. cit.* (1938), p. 117.

[409] N. L. Taliaferro, *op. cit.* (1933), p. 28.

Snake Ridge formation on the southern slope of La Morita Mountain does not constitute proof that part of the formation is marine because the pebbles and cobbles of the conglomerate were derived from the sandstone and limestone of the underlying Mural formation, which contains *Ostrea* and *Exogyra* in abundance. Likewise the presence in the Packard shales "of a few small, thin-shelled marine pelecypods" and "a few poorly preserved Foraminifera"[410] that have not been identified generically is not sufficient evidence that the shales are marine, especially as the distribution of marine beds of Campanian-Maestrichtian age in Chihuahua, Texas, and New Mexico indicates that the shore line was about 300 miles east of the Cabullona area.

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COMO BLUFF ANTICLINE, ALBANY AND CARBON COUNTIES, WYOMING[1]

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ABSTRACT

Como Bluff anticline is a westward-plunging, asymmetric fold extending across the east-central part of the Laramie Basin. The northeast axial trend of the anticline is nearly normal to the axial trends of the Laramie Basin and the Laramie Range. The northwest and steeper flank of the anticline is faulted by the North Como thrust. The thrust plane dips southeast. The fold probably originated from northwest-southeast compressive stresses. A geologic map of the western quarter of the anticline, interpretative structure sections, and detailed stratigraphic sections are given. The area has been made geologically famous by successful excavations for dinosaurs and other Jurassic reptiles.

INTRODUCTION

Location.—The Como Bluff anticline is located in Albany and Carbon counties, Wyoming (Fig. 1). It extends from the western slope of the northward-trending Laramie Range westward into the Laramie Basin. This anticline terminates 5 miles east of the town of Medicine Bow, Carbon County, Wyoming. Approximately 30 square miles were mapped in Ts. 22 and 23 N., Rs. 77 and 78 W. The western quarter of the anticline was included in this survey.

Purpose of report.—This work was undertaken with the aid of the department of geology of the University of Wyoming, and the Geological Survey of Wyoming to obtain: (1) an accurate geologic map of the region, (2) a detailed stratigraphic section, (3) a report of the geologic structure of Como Bluff anticline, (4) a generalized account of the economic values of the region, and (5) additional general geologic knowledge of Wyoming.

Previous geologic investigations.—This locality has been made geologically famous by the findings of fossilized reptiles during the 1880's and 1890's. Their occurrence in the low-dipping Jurassic Morrison formation on the south flank of the anticline has promoted great excavations by vertebrate paleontologists. Many famous scientists have worked in the area, including O. C. Marsh, Henry Fairfield Osborn, Richard S. Lull, Frederic B. Loomis, Barnum Brown, and W. H. Reed. However, the studies of these men were chiefly limited to vertebrate paleontology. Because of the excellent exposures, many stratigraphic sections have been measured across Como Bluff anticline. Dobbin, Hoots, Dane, and Hancock (6: 137–38), Darton and Siebenthal (4: 26, 28), and Darton (3: 441–44, 445) give reference to sections measured at Como Ridge. W. C. Knight (10: 384) speaks of the Como stage and gives Jurassic faunal lists. Giddings (7: 14, 37) comments on the Como fault and the various exposures. Darton, Blackwelder, Eliot, and Siebenthal (5: 8) mention the vertebrate fauna at Como Bluff. This

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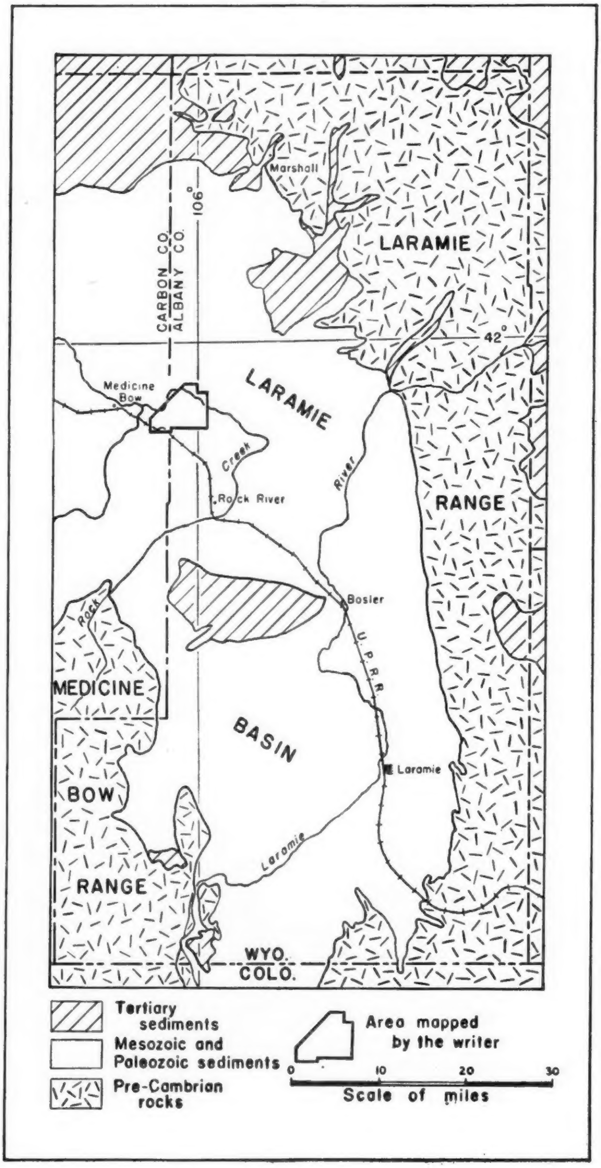
Marshall
106°
CARBON CO.
ALBANY CO.
LARAMIE
42°
Medicine Bow
LARAMIE
Creek
Rock River
River
RANGE
Rock
Bosler
U. P. R.R.
MEDICINE
BASIN
Laramie
BOW
Laramie
RANGE
WYO.
COLO.
Tertiary sediments
Mesozoic and Paleozoic sediments
Pre-Cambrian rocks
Area mapped by the writer
0 10 20 30
Scale of miles

FIG. 1

paper and the detailed map are the first of this nature ever presented about the area.

Field work.—The area was mapped on the scale of 1 inch equals 1,000 feet, by using stadia rod with telescopic alidade and plane table. A base line along the high Dakota ridge on the south flank was established. The Wall Creek sandstone was used as a mapping boundary except on the east and open end of the anticline where Rock Creek was chosen as the boundary. Field work was carried on for 6 weeks during the last half of the summer of 1941 under the direction of S. H. Knight. Field expenses were furnished by the Geological Survey of Wyoming. The entire area mapped is included in the topographic sheet of Como Ridge, Wyoming.

Accessibility.—The west margin of the area mapped is crossed by the Lincoln Highway (U.S. 30), and by the Union Pacific Railroad. Near the east margin of the area, the graded county road to Marshall, Albany County, Wyoming, crosses the anticline. Numerous trails are scattered throughout the region.

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TOPOGRAPHY

Como Bluff anticline is a broad westward-plunging fold. The resistant beds of the south flank give rise to a prominent hogback known as Como Bluff. The corresponding beds of the north flank lie in and border the valley of Rock Creek and do not give rise to a comparable hogback.

SOUTH FLANK

Como Bluff has an average elevation of 7,100 feet and stands several hundred feet above the surrounding country. The hogback trends east and in most places parallels the strike of the beds. It is capped by the resistant lower Dakota sandstone. The less resistant Morrison formation is exposed in the northward-facing, steep slope of the ridge. Erosion of the variegated shales of this formation gives rise to miniature badlands. The Sundance and Jelm formations are exposed in the lower part of this ridge. The Chugwater sandstones and red shales are exposed in the core of the anticline. South of the crest of the ridge is a long gentle slope controlled by beds of comparatively low dip. Several thin-bedded resistant sandstones of the Dakota and Thermopolis formations, the Mowry siliceous shale, and the Wall Creek sandstone form small eastward-trending hogbacks. The less resistant intervening black shales are eroded into shallow valleys.

NORTH FLANK

The beds on this flank of the anticline are nearly vertical and in places are overturned. Here, the resistant beds form minor hogbacks. The strike of the beds is northeast. The less resistant shales are inconspicuous as land forms. The elevation of the Wall Creek outcrop is approximately 6,700 feet and the thicker Dakota sandstone ridge stands about 100 feet higher in elevation.

The nose of the westward-plunging anticline stands at a lower elevation and is crossed by the highway and the railroad.

In summary, the Dakota of the south flank forms a prominent hogback. Also on the south flank, subordinate hogbacks paralleling the main ridge are formed by the Mowry siliceous shale and the Wall Creek sandstone. On the north flank, the Dakota forms a northeastward-trending, well defined minor hogback lying at a lower elevation than Como Ridge. The Frontier black shales, the Morrison variegated shales on the flanks, and the Chugwater red shales in the core of the anticline are non-resistant and do not have pronounced relief.

DRAINAGE

The entire area north of Como Ridge is drained by Rock Creek. Here, Rock Creek flows in a westerly direction and empties into the Medicine Bow river 2 miles northwest of this area.

The area south of Como Ridge is cut by westward-draining intermittent streams which empty into the Medicine Bow River.

A small lake, known as Aurora Lake, occupies a depression in the Chugwater shales. The axis of the anticline passes near the south shore of the lake. The steeply dipping Jelm sandstone crops out along the north shore of the lake. The straight north shore of the lake follows the strike of this bed. On the east, also in the Chugwater shales, are smaller lakes and swamps fed by the overflow of the Medicine Bow water wells and near-by Union Pacific Railroad springs. This water also collects in depressions near the axis of the anticline.

Along the eastern margin of the mapped area, Rock Creek cuts diagonally across the anticline. In this region, the heavy flow of water after rains is carried to the creek by deep gullies cut along strike-valleys. Near the Swan Company ranch and the State Fish Hatchery several springs drain into Rock Creek.

STRATIGRAPHY

GENERAL STATEMENT

The Laramie Basin within which the area described is located, is underlain by thousands of feet of Paleozoic and Mesozoic rocks. The stratigraphic succession is well known.

The oldest exposures in the area mapped are beds of the lower Chugwater formation. However, because of the rise of the anticlinal axis on the east, beds

older than Chugwater are exposed along the anticline. Giddings (7: 14), discusses these pre-Chugwater formations as well as the crystalline core of the anticline where they are exposed some miles east.

TABLE I

GENERALIZED STRATIGRAPHIC SECTION OF COMO BLUFF AREA, WYOMING

Age	*Unit Mapped*	*Thickness (Ft.)*	*General Description*
Upper Cretaceous	Carlile shale		Soft black shale and gray calcareous shale
	Wall Creek sandstone	27	Brown to white platy salt and pepper sandstone containing: *Inoceramus fragilis, Scaphites warreni, Prionocyclus wyomingensis, Ostrea sp.* and shark teeth
	Frontier shale	700	Black fissile to platy shale with septarian concretions
	Mowry shale	130	Black to brown platy siliceous fossiliferous shale which weathers to silver-gray color. Thin bentonite seams are present
	Thermopolis shale	80	Dark gray to black shale with thin beds of brown sandstone. A few scattered ironstones
Lower Cretaceous	Dakota group	220	Alternating brown blocky quartzitic sandstones and black shale. Pink, black, and green shale. White fine-grained to coarse-grained conglomeratic sandstone. Brown to gray massive sandstone weathering to mottled maroon-orange color
Upper Jurassic	Morrison formation	300	Largely variegated shale. Gray sandstone. Gray-brown fresh-water limestone. Lenses of limestone pebble conglomerate. Vertebrate remains
	Sundance formation	204	Yellow fine-grained platy sandstone. Olive-drab shale containing *Belemnites densus.* Gray thin-bedded sandstone. Gray sandy shale. Buff massive sandstone
Triassic	Jelm formation	94	Tan sandstone. Red sandy shale. Lenses of green and maroon conglomerate
	Chugwater formation	868	Predominantly orange-red sandy shale. Gray sandstone. Alternating red and green sandy shales. Gypsiferous red shale. Gray jagged and marly limestone
Permian	Embar group		Orange-red shale and gray limestones

The beds exposed in that part of Como Bluff anticline under consideration are shown in the generalized stratigraphic section, Table I, and in the detailed sections listed on the following pages. Thickness was measured normal to the strike of the beds with a Brunton compass and a steel tape with corrections for slope angles.

PRE-CAMBRIAN ROCKS

The pre-Cambrian rocks exposed in the Laramie Range (Fig. 1), as noted by Giddings (7: 9), are gray schists and gneisses made up of quartz, mica, and feld-

spar. In the pre-Cambrian exposures in the east end of Como Bluff anticline, much varied intrusive material is found. Island-like exposures of pure white quartz, pegmatites, basic dikes, and scattered diabasic masses are abundant in the exposures.

PRE-CHUGWATER ROCKS

The first sedimentary unit lying on the pre-Cambrian granitic complex consists of approximately 50 feet of redbeds composed of conglomerates, sandstones, and shales. Darton (3: 413) correlated these beds with the Pennsylvanian Amsden formation. However, in this paper, because the distinction between the Amsden and the Tensleep is not clear in this area, all of the Pennsylvanian beds are called Tensleep. The basal conglomerate was found to contain molds and imprints of Mississippian fossils. Darton believed that long periods of exposure before the deposition of the Amsden probably removed all of the Mississippian Madison limestone from this area. Overlying the Amsden beds is found about 325 feet of Pennsylvanian Tensleep (also called Casper) formation. These beds consist of cross-bedded sandstones and interbedded sandstones and limestones. Overlying the Tensleep formation are the Permian Satanka red shales and thin limestones, about 200 feet in total thickness. The 15-foot thick Permian Forelle limestone separates these beds from the lower Chugwater. The only part of the Chugwater not exposed in the mapped area consists of approximately 50 feet of red sandy shale which rests directly on the Forelle.

PERMIAN-TRIASSIC ROCKS

Chugwater formation.—The total thickness of the Chugwater formation is approximately 868 feet, of which the upper 815 feet is exposed in the area mapped. The lowest lithological unit exposed is a limestone which occurs 54 feet above the base of the Chugwater as defined by Thomas (17: 1680) in his Freezeout Hills section. In the measurement of the section in this area, the Jelm-Chugwater contact was taken at the base of a buff cross-bedded sandstone. Throughout the Laramie Basin area, the Chugwater formation rests on the crinkly Forelle limestone. The Chugwater formation consists mainly of red sandy shale and red sandstone with subordinate amounts of gray sandstone, gypsum and thin beds of limestone. Thomas (17: 1660) states that the Chugwater is a lithologic unit embracing rocks of both Permian and Triassic age, and a unit with a different age for its basal beds in different localities. Darton and Siebenthal (4: 22–23) measured 1,133 feet of Chugwater which included the Jelm.

Thomas points out (17: 1687) that along the north flank of the Como Bluff anticline the Little Medicine tongue of the Dinwoody formation (17: 1670) and a part of the lower Freezeout tongue of Chugwater (17: 1670) are exposed. In order to map the desired structure within the lower part of the Chugwater formation, four exposed thin beds of porous limestone were used. The Little Medicine tongue is the upper and outermost limestone used in mapping the structure. The

STRATIGRAPHIC SECTION OF PART OF CHUGWATER FORMATION EXPOSED IN SECS. 26, 27, AND 35, T. 23 N., R. 77 W.

	Feet
Jelm formation	
Chugwater formation	
Red sandy shale	9
Gray platy sandstone	3
Gray-green sandy shale	6
Gray fine-grained massive resistant sandstone	12
Red shaly sandstone	25
Greenish gray shaly sandstone	3
Red shaly sandstone with 6-inch beds of greenish gray sandstone	72
Green finely crystalline platy sandy limestone; weathers brown	1
Red sandy shale, green sandy shale, and red shaly sandstone	57
Greenish gray shaly massive sandstone	30
Red sandy shale with several 1-foot thick sandstones near top	295
Red sandy shale	127
Little Medicine tongue of Dinwoody	
Buff fine-grained shaly salt-and-pepper sandstone at top and becoming more shaly in middle. Limestone at bottom; all red-stained	11 (No. 1 ls.)*
Yellow to buff salt-and-pepper sandstone and oölite	1
Dove-colored shale	2
Base of section	
Freezeout tongue of Chugwater	

*See footnote in following table.

STRATIGRAPHIC SECTION OF FREEZEOUT TONGUE OF CHUGWATER, MEASURED NEAR DIFFICULTY POST OFFICE, FREEZEOUT HILLS, CARBON COUNTY, WYOMING, BY THOMAS (17: 1680)

	Feet
Little Medicine tongue of Dinwoody	
Freezeout tongue of Chugwater	
Covered portion, probably mostly red shale; in Flat Top uplift this part consists of red shales and thin breccias. Exact thickness not measureable	20
Porous, impure, massive gray limestone	2 (No. 2 ls.)*
Variegated, red and olive, gypsiferous shale	16.5
Gypsum	3
Breccia; angular masses of gray limestone in red shale matrix	6 (No. 3 ls.)
Breccia; angular fragments of red shale and crinkled limestone in gray limestone matrix	4
Red shale	2
Breccia; angular fragments of crinkled limestone and red shale in gray limestone matrix grading downward into crinkly limestone	2 (No. 4 ls.)
Gray shale	1
Breccia; red shale fragments in limestone matrix	0.2
Breccia; red, sandy shale fragments in matrix of same character	2
Fine-grained, finely laminated, slightly crinkled white limestone	1.5
Red sandy shale with numerous circular gray spots	50**
Total thickness of Chugwater	868
Forelle formation	

* Numbers are writer's and refer to limestones within the lower portion of the Chugwater.
** This portion of Thomas' section is not exposed in the mapped area.

three lower limestones are contained in the Freezeout tongue. Thomas, in describing the Freezeout tongue, measured a section approximately 20 miles northwest of this area. This section is given as representative of that part of the Chugwater which is not exposed or too poorly exposed to be measured in detail.

TRIASSIC ROCKS

Jelm formation.—This formation, consisting of buff massive cross-bedded sandstone, conglomeratic lenses, and red sandy shale, was originally described by Knight (8: 168). The formation takes its name from Jelm Mountain near the Wyoming-Colorado state boundary. The total thickness measured in the mapped area was 94 feet. The upper contact was chosen at the top of the conglomerates. The basal contact was taken at the bottom of the tan cross-bedded sandstone just above the uppermost characteristic Chugwater red shale.

STRATIGRAPHIC SECTION OF JELM FORMATION, MEASURED IN SEC. 26, T. 23 N., R. 77 W.

	Feet
Sundance formation	
Jelm formation	
Lenses of variable green conglomerate with white mica, green shale, and red sandstone particles; round stones not more than ⅛ inch in diameter	1
Lenses of dirty maroon conglomerate with limestone pellets; ridge-former	1
Red to pink sandy shale; non-resistant	52
Tan to buff coarse-grained massive cross-bedded resistant sandstone with calcite-cemented veinlets	40
Total	94
Chugwater formation	

UPPER JURASSIC ROCKS

Sundance formation.—The Sundance formation is well exposed in this area and is 204 feet in thickness. The top member of the formation is lemon-yellow sand. A middle unit of olive-drab shale contains abundant guards of the cephalopod, *Belemnites densus*. The base was drawn at the contact of the white sandstone and the typical Jelm conglomeratic lenses. The lower unit of sandstone approximately 90 feet thick is believed to be the stratigraphic equivalent of the Nugget sandstone. This sandstone in the Freezeout Hills section has been tentatively correlated by Neely (14: 724) with the Nugget sandstone.

STRATIGRAPHIC SECTION OF SUNDANCE FORMATION, MEASURED IN SEC. 26, T. 23 N., R. 77 W.

	Feet
Morrison formation	
Sundance formation	
Lemon-yellow fine-grained platy semi-friable sandstone	6
Dark green-gray drab shale with *Belemnites densus* beginning to appear 15 feet below yellow sandstone	40
Gray platy soft sandstone	1
Olive-drab shale	5
Gray platy sandstone	1
Olive-drab shale	17
Gray platy soft sandstone	7
Green, gray, and red shale	26
Gray thin-bedded cross-laminated sandstone	3
Gray sandy shale	7
Buff to yellow massive soft sandstone; very fine-grained at top grading to medium-grained and coarse-grained near bottom	80
White medium-grained massive sandstone	11
Total	204
Jelm formation	

Morrison formation.—The thickness of the Morrison measured across the dinosaur-graveyard excavation pits is 308 feet. This world-famous formation consists chiefly of variegated shales, thin sandstones, lenses of limestone conglom erate, and fresh-water limestones at the base. Exposures of this formation have yielded many fossil reptile remains. For this reason the name Como Bluff is usually associated with the name, "Dinosaur Graveyard."

STRATIGRAPHIC SECTION OF MORRISON, MEASURED IN SEC. 17, T. 22 N., R. 77 W.

	Feet
Dakota group	
Morrison formation	
Black, green, red, purple, brown, and maroon variegated shale; weathers to gray clay-balls of pea size	209
Gray fine-grained soft but platy friable sandstone with very thin conglomerate at bottom	17
Green and red shale	5
Brown, gray, red, purple, and green mottled limestone	2
Red, gray, and green shale	28
Gray fine-grained soft sandstone	5
Variegated shales	5
White fine-grained massive semi-friable sandstone	5
Variegated shales	9
White fine-grained platy sandstone	4
Variegated shales	9
Gray-brown finely crystalline massive limestone with conspicuous calcite crystals and calcite-recemented fractures	4
Green and gray shale; lenses of limestone pebble conglomerate with round stones up to $\frac{3}{4}$ inch in diameter	6
Total	308
Sundance formation	

CRETACEOUS ROCKS

Dakota group.—The rock succession lying between the Morrison formation and the Thermopolis shale has been described by Lee (12: 18) as the Dakota group. On the geologic map (Fig. 2) they are shown as a unit. They are 220 feet thick at Como Bluff. These rocks consist of several alternating black shales and brown blocky quartzitic sandstones forming minor hogbacks, pink to purple, black, and green shales, and a white sandstone with a basal conglomerate. The resistant lower conglomeratic sandstone caps Como Ridge on the south flank of the Como Bluff anticline.

Thermopolis shale.—The Thermopolis shale consists of dark gray to black non-resistant shales with several thin beds of gray platy sandstone containing marks resembling worm trails. A few scattered ironstone concretions are also present. The total thickness is 80 feet.

Mowry shale.—At Como Bluff the thickness of the Mowry shale is 131 feet. This compares favorably with that of Dobbin and associates (6: 139). It is a black to brown platy siliceous shale which weathers to a characteristic silver-gray color and contains fossil fish scales. Bentonite seams are interbedded with the shale. The resistant character of these shales gives rise to prominent ridges commonly covered with scattered pine trees. The fact that this formation gives

rise to ridges, taken together with the characteristic silver-gray color, makes it one of the most easily recognizable horizon markers exposed in this area.

Frontier formation.—In the region mapped, the Frontier formation consists of 700 feet of dark gray to black shales becoming more sandy toward the top. Septarian concretions occur near the base.

Wall Creek sandstone.—A sandy shaly succession at the top of the Frontier formation is called the Wall Creek. In the northern part of the Laramie Basin, the Wall Creek is divisible into several sandy zones. Dobbin and associates (6: 139), point out that this sandstone may not be the exact stratigraphic equivalent of the oil-producing sands of the same name in the central part of Wyoming. The bed as found in the mapped area consists of brown fossiliferous sandstone 27 feet in thickness. It is a ridge-forming unit and is easily discernible.

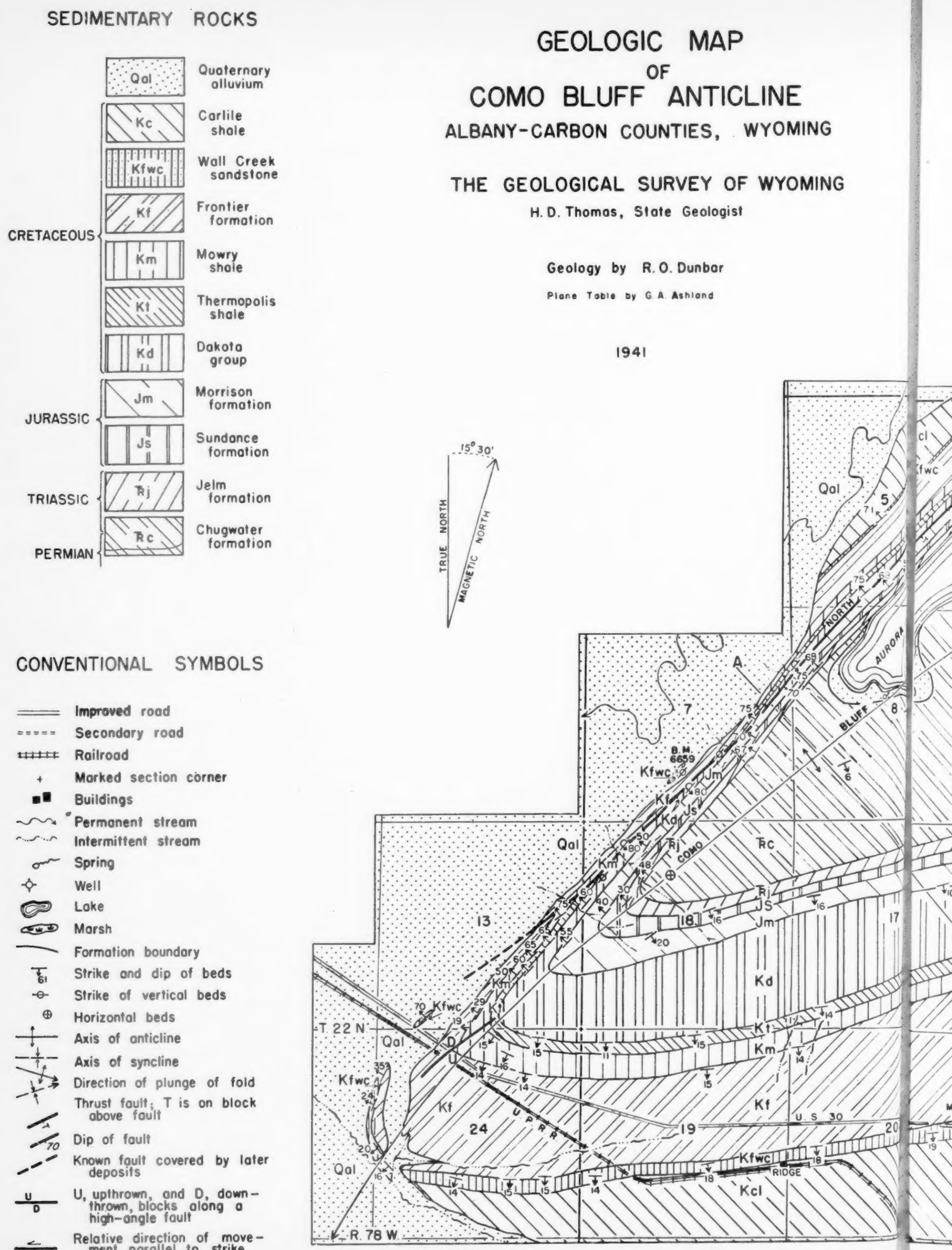
Carlile shale.—The Carlile shale consists of soft black shale and gray calcareous shale containing large ironstone concretions. The thickness given by Beckwith (1: 1520) for the Laramie Basin is 250 feet. Thomas (18: 1196) showed that the fauna of the so-called Carlile of the Laramie Basin is Niobrara in age. He suggested that the name Sage Breaks shale member of the Niobrara proposed by Rubey (15: 4) be used for the shale immediately above the Wall Creek sandstone in the Laramie Basin. These beds were mapped as the Carlile shale.

STRATIGRAPHIC SECTIONS OF THERMOPOLIS, MOWRY, FRONTIER, AND WALL CREEK FORMATIONS, MEASURED IN SECS. 18 AND 19, T. 22 N., R. 77 W.

	Feet
Carlile shale	
Wall Creek sandstone	
Brown above and white below medium- to coarse-grained cross-bedded and platy fossiliferous salt-and-pepper sandstone containing: *Scaphites warreni, Inoceramus fragilis, Prionocyclus wyomingensis, Ostrea* sp., and numerous shark teeth associated with rounded black chert pebbles	27
Frontier formation	
Black fissile to platy sandy shale	60
Dark gray and black fissile to platy shale with septarian concretions about 100 feet from bottom. Shale becomes lighter in color and more sandy near top	643
Total	703
Mowry shale	
Black to brown platy siliceous fossiliferous shale which weathers to silver-gray color and contains fossil fish scales; thin bentonite seams	131
Thermopolis shale	
Dark gray to black platy non-resistant shale with 6-inch bed in middle of gray platy well cemented resistant sandstone containing marks resembling worm trails. A few scattered ironstone concretions	80

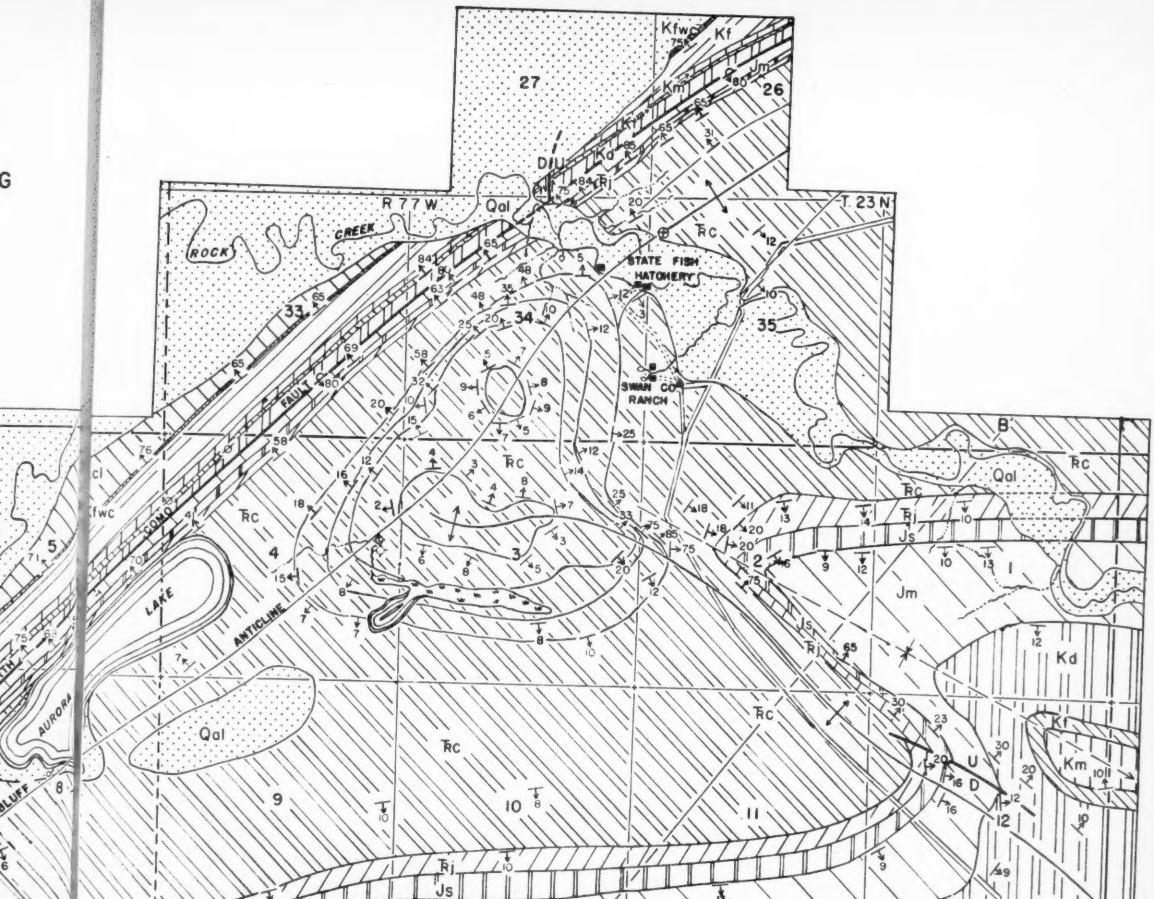
STRATIGRAPHIC SECTION OF DAKOTA FORMATION, MEASURED IN SEC. 18, T. 22 N., R. 77 W.

	Feet
Thermopolis shale	
Dakota group	
Brown fine-grained blocky well cemented resistant quartzitic sandstone forming dip-slope and minor hogback	3
Black shale with gray-green weathered sandy limestone 6 inches thick containing marks resembling worm borings	18



GEOLOGIC MAP
OF
COMO BLUFF ANTICLINE
ALBANY-CARBON COUNTIES, WYOMING
THE GEOLOGICAL SURVEY OF WYOMING
H. D. Thomas, State Geologist
Geology by R. O. Dunbar
Plane Table by G. A. Ashland
1941
SEDIMENTARY ROCKS
Qal Quaternary alluvium
Kc Carlile shale
Kfwc Wall Creek sandstone
Kf Frontier formation
Km Mowry shale
Kt Thermopolis shale
Kd Dakota group
Jm Morrison formation
Js Sundance formation
Ꞧj Jelm formation
Ꞧc Chugwater formation
CRETACEOUS
JURASSIC
TRIASSIC
PERMIAN
CONVENTIONAL SYMBOLS
Improved road
Secondary road
Railroad
Marked section corner
Buildings
Permanent stream
Intermittent stream
Spring
Well
Lake
Marsh
Formation boundary
Strike and dip of beds
Strike of vertical beds
Horizontal beds
Axis of anticline
Axis of syncline
Direction of plunge of fold
Thrust fault; T is on block above fault
Dip of fault
Known fault covered by later deposits
U, upthrown, and D, downthrown, blocks along a high-angle fault
Relative direction of movement parallel to strike of high-angle fault
15° 30'
TRUE NORTH
MAGNETIC NORTH
NORTH
AURORA
BLUFF
COMO
RIDGE
U. P. R. R.
U. S. 30
T. 22 N.
R. 78 W.
B. M. 6659
Kcl

FIG. 2



R. 77 W.
T. 23 N.
T. 22 N.
ROCK
CREEK
STATE FISH HATCHERY
SWAN CO. RANCH
COMO
FAULT
ANTICLINE
LAKE
AURORA
BLUFF
MUSEUM
B.M. 7143
CARBON CO.
ALBANY CO.
Qal
Kfwc
Kf
Km
Jm
Kd
Kt
Kcl
Js
Kcl
A′
B
B′
U
D
SCALE
THOUSAND FEET
3 MILES

	Feet
Gray-brown fine-grained platy to blocky resistant sandstone forming dip-slope and minor hogback	6
Black and gray shale	4
Light gray to white fine-grained massive and cross-bedded resistant sandstone; forms minor hogback	6
Black shale with small beds of brown sandstone and bands of ironstone concretions	45
Buff to brown platy sandstone	4
Gray fine-grained platy sandstone weathering brown	2
Buff fine-grained platy sandstone with odd conchoidal-like fracture and surface marked by odd concentric rings	15
Black and gray shale	4
Brown medium-grained massive resistant jointed sandstone and some conglomerate	18
White to gray fine-grained massive sandstone to conglomerate; highly cross-bedded, resistant, and cut with siliceous veinlets	49
Gray shale	8
Brown sandstone	3
Pink, black, and green shale with two thin brown sandstone beds	20
Brown to gray fine-grained massive resistant sandstone with some gray platy sandstone in thin beds and siliceous veinlets; weathers gray to mottled maroon-orange color	14
Total	219

Morrison formation

STRUCTURE

GENERAL RELATIONS

The Laramie Basin is a synclinorium whose elongate axis extends northward. The Como Bluff anticline is a transverse fold in the central part of this basin. The axis of the anticline extends from the west flank of the Laramie Range in a southwesterly direction for a distance of approximately 25 miles to a point 5 miles southeast of the town of Medicine Bow. The Como Bluff anticline is bordered on the north by the Bone Creek syncline; this syncline separates the Como Bluff anticline from the Flat Top anticline. The Como Bluff anticline is bordered on the south by a syncline or synclines which separate it from the East Foot Creek anticline and the Gillespie anticline. The axial trends of the Flat Top anticline, Como Bluff anticline, and Gillespie anticline are approximately parallel; the axial planes dip southeast.

COMO BLUFF ANTICLINE

This structure is located in Albany County with the exception of the westernmost 5 miles, which lies in Carbon County. The fold causes a deflection in the trend of the pre-Cambrian rocks of the Laramie Range (4: 52). It is a strongly asymmetric fold and is faulted on the steep northern flank. In general, the beds on the north flank strike N. 45° E. and dip 80° NW.; in places the beds are vertical and overturned. The beds on the south flank strike N. 80° E. and dip 10°–20° S. The axial plane dips 70°–75° S. These relations are shown in the structure section *AA'* (Fig. 3).

The major anticlinical axis plunges west. The fold trends northeast in the region east of the area mapped. It finally meets the mountain front at an angle of nearly 90°. In the area mapped the axis trends northeast through Secs. 26, 35, and the E. ½ Sec. 34, T. 23 N., R. 77 W. Through the S. ½ Sec. 34, the trend

changes to N. 25° E. In the NW. ¼ Sec. 3, T. 22 N., R. 77 W., the trend is also northeast and this trend persists southwest through the nose of the anticline. The fold dies out in Sec. 24, T. 22 N., R. 78 W. The curvature of the Wall Creek sandstone in the W. ½ Sec. 24, clearly shows the structural relations of the nose of the anticline.

The Chugwater formation is exposed in the core of the anticline. On the south flank these beds near the top of the formation dip 6°–8° S. On the north flank these beds dip 65° N. Four thin Chugwater limestones reveal a heart-shaped dome along the axis of the anticline in Secs. 3 and 4, T. 22 N., and in Sec. 34, T. 23 N., R. 77 W.

Along the south flank in Sec. 12, T. 22 N., R. 77 W., the strike of the beds changes abruptly from N. 80° E. to N. 45° W. In Sec. 2, the strike changes from N. 45° W. to N. 80° E. The abrupt change of strike gives rise to an S-shaped structure.

A minor anticline is developed in Sec. 3, the axis of which trends southeast. A minor syncline is developed in Sec. 2, the axis of which also trends southeast. These minor folds plunge southeast. These relations are shown in the structure section *BB′* (Fig. 4).

The prominent Como Ridge on the south flank of the anticline is due to the resistant Dakota sandstones rising on a gentle dip of 10°–14°.

The S-shaped structure and the dome-shaped rise of the beds probably are the results of differences of strength or structural relationships within the pre-Cambrian basement complex at the time of folding.

NORTH COMO FAULT

The North Como fault is the name employed to designate the thrust fault along the steep north flank of the Como Bluff anticline. The fault extends southwesterly from the pre-Cambrian of the Laramie Range in T. 24 N., R. 73 W. (7: Pl. xi), with a remarkably uniform strike, through the area mapped into Sec. 13, T. 22 N., R. 78 W., where it disappears beneath the alluvium of the Rock Creek valley. The thrust plane dips 70° S. This observation was taken along a gully 20 feet deep in the NE. ¼ Sec. 7, T. 22 N., R. 77 W.

The following discussion traces the fault from its west end, northeast toward the Laramie Range. In the east part of Sec. 13, T. 22 N., R. 78 W., the fault traverses the lower part of the Frontier. Farther west the fault is covered with alluvium. In the SW. ¼, NW. ¼ Sec. 18, T. 22 N., R. 77 W., the fault cuts across the Mowry and the Thermopolis. In the S. ½ Sec. 7, the Mowry wedges out and the Dakota is thrust upon Frontier. In the E. ¼ Sec. 7, the fault is parallel with the strike of the Morrison. A sudden thinning of the Morrison clays was observed at this point. A conspicuous transverse gully has developed along the trace of the fault where it cuts across the Dakota. Through the rest of the area mapped the fault lies in the Morrison. The geologic map (Fig. 2) shows a minor change of the strike of the beds and the strike of the fault from N. 45° E. in Sec. 33, T. 23 N.,

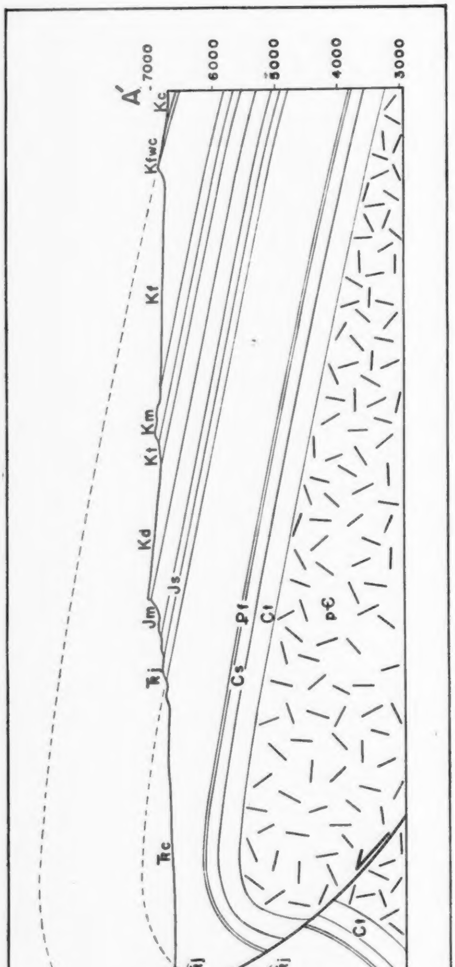

A
A'
Qal
Km
Kt
Kfwc
Kf
Kd
Jm
Js
Ŧj
Ŧc
Kc
Cs
Pf
Ct
pЄ
7000
6000
5000
4000
3000

FIG. 3

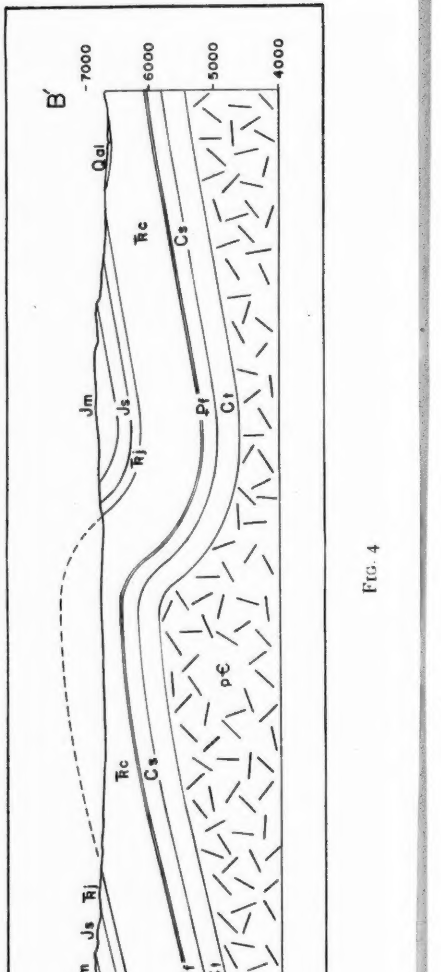

B
B'
Kd
Jm
Js
Ŧj
Ŧc
Qal
Cs
Pf
Ct
pЄ
7000
6000
5000
4000

FIG. 4

R. 77 W., to N. 55° E. in Sec. 34. The North Como fault east of the mapped area has been described by Giddings (7).

The general thinning of the Morrison as it is traced northeastward along the strike, and the minor distortions in the Dakota rocks adjacent to the Morrison, are evidence of the presence of the fault. It is to be expected that the fault would follow a zone of weakness, such as the poorly consolidated Morrison clays.

The south block is the apparently upthrown block. It is believed that the greatest amount of displacement occurs in the pre-Cambrian and decreases upward through the sediments. From measurements taken along the projected fault plane shown in the structure section *AA′* (Fig. 3), the displacement along the fault plane of the pre-Cambrian-sedimentary contact is 500 feet. Measurements of that part of the structure section drawn above the ground indicate a displacement of the Wall Creek-Frontier contact of approximately 100 feet. In the drawing of these structure sections, the beds were drawn as concentric. No attempt was made to employ variation in the crestal and flank thicknesses.

MINOR FAULTS

In the S. $\frac{1}{2}$ Sec. 27, T. 23 N., R. 77 W., a fault extends northward from the North Como fault. This nearly vertical fault strikes due north and makes a 45°-angle with the northeast strike of the major thrust. North beyond the Dakota hogback the fault is obscured by alluvium. The fault is visible where it offsets the tan and black beds of the Dakota in the south face of the hogback. This fault is probably a vertical tear fault. The major component of the net-slip is strike-slip. There is little evidence of dip-slip movement. The horizontal displacement is about 50 feet.

In the N. $\frac{1}{2}$ Sec. 24, T. 22 N., R. 78 W., on the nose of the westward-plunging anticline, the resistant Mowry shale is highly distorted by a fault striking N. 50° E. There is about 200 feet of offset of the Mowry beds. The fault dies out at the east in the Thermopolis shale and at the west in the Frontier shale. This tension fault resulted from the sharp flexure of the beds at this point during the folding of the anticline.

A nearly vertical fault striking N. 50° W. occurs in the NW. $\frac{1}{4}$ Sec. 12, T. 22 N., R. 77 W. Here, the Sundance and the Jelm beds are offset about 100 feet. The fault dies out northwest in the Chugwater shales and southeast in the wide outcrop of the Dakota. This tension fault was the result of the sharp flexure of the beds at the time the S-shaped structure was formed.

ORIGIN OF COMO BLUFF ANTICLINE AND THRUST

The axial trend of the Laramie Range anticline is deflected in a broad arc extending from north to west. This westward deflection begins at a point nearly due east of the region under discussion, which therefore lies on the inner or concave side of the arc. This area was a zone of compression due to the crowding of the materials within the arc. Here compressional forces would operate in direc-

tions paralleling chords of the arc, or in this area, in a north-northwest direction Within the area of the arc the direction of least resistance or direction of maximum relief to the compressive stresses is upward.

The Como Bluff anticline trends northeast or normal to the direction of compression. A thrust in the pre-Cambrian dipping southeast is to be expected from an interpretation derived from the application of the strain-ellipsoid theory. Beckwith (2: 1475), discusses a similar thrust that probably was initiated in the pre-Cambrian and was propagated upward into the sediments. The sediments are gradually warped into a steep monocline in front of the edge of the growing fracture. As the fracture penetrated the monocline it was deflected upward by the stratification in the vertical beds, such as are found on the north flank of Como Bluff anticline. As analyzed by Beckwith, this produces a thrust which steepens as it cuts upward through the sediments toward the surface. It is believed that the thrust has a nearly uniform dip in the pre-Cambrian. This interpretation explains the high dip of the plane of the thrust at the present ground surface. Surfaceward propagation of such a pre-Cambrian thrust fault by continued horizontal compression would give rise to an anticlinal fold and thrust fault, such as the Como Bluff anticline and the North Como fault.

STRUCTURAL SUMMARY

The northeast-trending transverse folds extending across the east-central part of the Laramie Basin are asymmetric, with the steeper flanks of the anticlines on the north. These folds are in some places faulted by a southeastward-dipping thrust. Such folds were the results of a general northwest-southeast compression with the predominant direction of maximum relief upward. These movements are believed to have occurred intermittently through late Upper Cretaceous and Paleocene time.

ECONOMIC VALUES OF REGION

SALINE DEPOSITS

In Albany County there are numerous deposits of sodium sulphates and magnesium sulphates in the bottoms of small lake depressions. About 15 miles north of the town of Rock River, Wyoming, and 4 miles east of the area mapped, these deposits occupy the lower parts of undrained excavations in the Chugwater formation. These deposits range from 1 acre upward to 90 acres.

W. C. Knight (11: 259) stated that those deposits are commonly covered with water after heavy rains. Upon the evaporation of the water layers of solid salts remain which range from thin crusts to beds several feet in thickness. Knight ascertained that the salts were derived from decomposing Chugwater sandstones and were transported by water to the natural depressions. Ordinarily, there is a regular gradation from the sodium salts in the upper basins to the magnesium salts in lower basins. As explained by Knight, this is a natural method of differen-

tiation. The magnesium salts having a greater solubility than the sodium salts are carried by high waters to the lower basins. Upon evaporation, the sodium salts are deposited in the upper basins and the magnesium salts in the lower basins.

In 1933, a detailed report on this subject was prepared for the Geological Survey of Wyoming by S. H. Knight (9). Among his samples collected for analysis were those from the largest lake, named Brooklyn or Pazeka Lake. The average figures obtained on the salt composition of this deposit were: 86 per cent epsomite and 5 per cent mirabilite. Because of this occurrence of nearly pure epsomite a large building has been erected on the edge of this lake to obtain and to purify Epsom salts for commercial use.

UNDERGROUND WATER

The succession and structure of the rocks in the Laramie Basin are favorable for the occurrence of large supplies of underground water. Most of the water-bearing sandstones are interbedded with relatively impervious shales, a condition favorable for underground storage.

Springs in the mapped area furnish an abundant supply of cold water of good quality. Because of this available source of water, a fish hatchery has been established in the narrow Rock Creek valley. This hatchery was founded by Tom Boylan, local pioneer, and is now owned and being developed by the State of Wyoming. Numerous springs were mapped adjacent to the hatchery in the NE. $\frac{1}{4}$ Sec. 34, T. 23 N., R. 77 W.

The domestic water supply for the town of Medicine Bow (Fig. 1), is furnished by two artesian wells in the NE. $\frac{1}{4}$ Sec. 4, T. 22 N., R. 77 W. The water is piped 9 miles and lifted into the town's elevated tank by the force of gravity. The two wells resulted from oil exploration wells drilled in 1920.

Immediately south and in the same section as the Medicine Bow wells are the Union Pacific springs. The roadbed of the railroad was formerly located near these springs. A large abandoned masonry reservoir lies down the slope from this supply. The entire flow draining from the reservoir and the overflow from the Medicine Bow wells drains into the lakes and swamps.

The domestic supply for the Swan Company ranch is furnished by springs mapped near the west section line of the SW. $\frac{1}{2}$ Sec. 35, T. 23 N., R. 77 W.

Several springs occur adjacent to the south shore of Aurora Lake which is located in the core of the anticline. Water from these springs drains into the lake.

In all of the foregoing locations, the water comes from the Chugwater red shales which are exposed on the surface and found in the core of the anticline. It is believed that the Tensleep sandstone is the chief source bed. About 15 miles east and at a higher elevation than this area the Tensleep formation has a wide outcrop and large catchment area where it is exposed in the core of the anticline. The thick sandstones of this formation are carried westward by their low dip toward the center of the Laramie Basin where they are covered by shales so that

the contained water is under considerable hydrostatic head. It is probable that water wells drilled into the Tensleep sandstone in the vicinity of the mapped area would yield water. Some of these wells would probably flow. Springs with a smaller water supply may have the upper Chugwater sandstones as their source beds.

Small springs found in the SW. ¼ Sec. 17, T. 22 N., R. 77 W., flow from the Mowry shale where it is exposed along the south flank of the anticline. These springs are of little importance as the water is either evaporated or absorbed after flowing a short distance along intermittent stream gullies. The source bed is the upper Dakota sandstone.

GYPSUM DEPOSITS

Extensive deposits of gypsum are found in the N. ½ Sec. 35 and in the S. ½ Sec. 26, T. 23 N., R. 77 W. These deposits are found in the Chugwater shales and in places change the general appearance from the characteristic red to a white color. The dip of the beds ranges from 20° N. to 10° S. The axis of the Como Bluff anticline passes through these sections; consequently, the beds are nearly horizontal in much of the area. No estimate of the available tonnage was attempted.

OIL POSSIBILITIES

In Sec. 34, T. 23 N., and Secs. 3 and 4, T. 22 N., R. 77 W., is a small anticlinal structure. In order to map this structure, four limestones of the lower Chugwater formation were used. The first limestone resembles the Little Medicine tongue of the Dinwoody formation described by Thomas (16). This bed can be followed through the afore-listed sections. It appears on the map (Fig 2) as a heart-shaped structure. Three other recognizable limestone units of the Freezeout tongue are also present. The red shale of the Freezeout tongue, exposed inside of the innermost limestone mapped, is the oldest exposed bed in this area.

The potential oil-bearing beds are the Satanka shales (Embar group), or more probably, the Tensleep sandstones. In near-by proved structures both of these formations were found void of oil. These beds elsewhere in Wyoming produce a black crude of low gravity.

In 1920, this structure was tested by the drilling of two wells in the NE. ¼ Sec. 4. Figure 2 shows that these locations are not on the center of the structure but on the west flank. Two artesian water wells flow from the Tensleep and now furnish the domestic supply for the town of Medicine Bow.

The low effective closure of about 60 feet and the large flow of fresh water from the Tensleep sands suggest that a well drilled on the crest of the dome would not encounter oil. As far as known to the writer the logs of the two test wells are unavailable.

BENTONITE

In this region bentonite deposits are found in the Mowry shale. The beds range in thickness from 5 feet to a few inches. It is not extensively excavated in

this locality but some of the clay is prepared in the powdered form and sold as a beauty-aid. Local deposits in the past have been used as a drilling-mud in near-by oil fields. Details concerning the bentonite deposits in Wyoming are published in the Wyoming Geological Survey *Bulletin 28*.

BRIEF HISTORY OF EXPLORATION OF DINOSAUR REMAINS

The Jurassic Morrison beds at Como Bluff have yielded an important fauna of Mesozoic reptiles. Many of these Wyoming specimens are displayed in distant museums. During the Mesosoic, turtles, lizards, crocodiles, and primitive mammals existed along with dinosaurs and their remains are found in the same beds.

W. H. Reed is given credit for the discovery of these Wyoming dinosaur deposits in 1877, just south of the now abandoned railroad station of Como. The list of famous paleontologists who have spent much time and field work at Como Bluff includes: O. C. Marsh, Henry Fairfield Osborn, Richard S. Lull, Frederic B. Loomis, Barnum Brown, and Reed.

A highly fossiliferous bed is found about 80 feet below the Dakota near the middle of the Morrison. It is a clay bed beneath a 4-foot band of sandstone. Simpson (16: 1), states that every order of non-marine vertebrate known to have been in existence during Upper Jurassic time, and smaller forms of other classes, are represented in the collection from one quarry at Como Bluff.

A small museum has been founded at Como Bluff, Wyoming, by Tom Boylan. The museum building, on U. S. Highway 30, is built entirely of fragments of fossilized dinosaur bones. Boylan has lived in this region for nearly 50 years and, as a youth, helped in the excavation work.

A complete and detailed discussion of the Wyoming dinosaurs has been written by Moodie (13).

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 28, NO. 8 (AUGUST, 1944), PP. 1217-1219

GEOLOGICAL NOTES

STANDARDIZATION IN COMPILING AND REPORTING DATA ON OIL RESERVES[1]

FREDERIC H. LAHEE[2]
Dallas, Texas

For a long time the petroleum industry has needed a standardized terminology and system for compiling and reporting data on oil reserves. Merely to state that the reserves of this country are so many barrels, with no explanation of what the figure actually represents, leads to endless confusion and misunderstanding. But let us hasten to add that when, in an original report, a clear explanation *is* given, and only part of this report is quoted, and the explanatory material is purposely omitted, usually to save space, then the blame for causing misunderstanding rests with the editor, or the reporter, or the speaker, whoever he may be, who quotes. If we, in the oil industry, are going to clarify this situation in the minds of the public and of government officials, and even in the minds of many in our own industry, we must come to a better understanding of the terminology and classification of crude-oil reserves, and we must agree to adopt and use a suitable classification based on this terminology.

In the estimates published annually since 1937 by the American Petroleum Institute, only "proved" or "blocked out" reserves of oil are included. These proved reserves are both drilled and undrilled. The *proved drilled reserves*, in any pool, include the oil estimated to be recoverable by the production methods already installed (whether primary or secondary) and from the area actually drilled up on the spacing pattern in vogue in that pool. The *proved undrilled reserves*, in any pool, include reserves under undrilled spacing units which are so close, and so related, to the drilled units that there is every reasonable probability that they will produce when drilled. Beyond these *proved* reserves, the A.P.I. committee does not go.

Certain committees of the Petroleum Administration for War make estimates not only of proved oil reserves, grouping these as drilled and undrilled, but also of additional oil reserves which they call "possible." These "possible reserves" include (1) oil which may be recoverable by the application of more efficient production methods (generally secondary, where only primary has been in use), and (2) oil which may be recoverable from "geologically possible extensions of underground reservoirs" considerably beyond the limits proved by wells already drilled.

[1] This paper, almost *verbatim*, was presented before the Spring meeting of the Southwestern Division of the American Petroleum Institute, on June 13, 1944, at Houston, Texas. Manuscript received, June 21, 1944.

[2] Chief geologist, Sun Oil Company.

These two classes of reserves may be regarded as already *discovered*, although they have not been *proved*.

There are other *possible reserves*—we are now using the adjective with its ordinary connotation—which have not yet been discovered. These include (1) oil which may be recoverable from undeveloped pools *above* producing pools; (2) oil which may be recoverable from undeveloped pools *below* producing pools; (3) oil which may be recoverable from new pools, not yet drilled, on producing geologic structures, but outside the limits of the pool or pools which have already been found on these structures; and (4) oil which may be recoverable on local geologic structures, or in local geologic environments, where no oil has yet been discovered, but where, because of conditions similar to those prevailing in other producing localities in the general region, there is a fair chance that new oil fields may eventually be found. All these four classes belong to *undiscovered possible reserves*. Note that they are all related to *known* local geologic structures or to *known* local geologic environments which are comparable with similar producing structures or environments in the same region.

Besides the proved reserves and possible reserves, as outlined in the foregoing there are *hypothetical reserves*, that is, reserves which may perhaps be present in non-producing regions which are underlain by sedimentary formations of the same age as, or of similar character to, sedimentary formations that yield oil in other regions. These reserves, if present, are certainly highly speculative and any attempt to estimate how large they are is purely a guess.

Finally there are *substitute reserves* which include (1) oil that may be made available by chemical processing of natural gas, and (2) oil that may be made available by distillation of oil shale, coal, and organic materials. These are not reserves of crude oil as such, but rather of substances from which oil can be derived.

Summarizing, we have the classes of oil reserves shown in Table A.

TABLE A

CLASSIFICATION OF OIL RESERVES

Crude-oil reserves	Proved reserves	Drilled
		Undrilled
	Possible reserves	Discovered
		Undiscovered
	Hypothetical reserves	
Substitute reserves		

If in every estimate of reserves the author would clearly state to which of these categories his figures apply, there would be much less confusion. The trouble is that one person may be talking of proved reserves only; another of proved plus possible discovered reserves; another of proved reserves plus all possible reserves, both discovered and undiscovered; another of all groups of crude-oil reserves

together; and sometimes, without too precise definition, substitute reserves and crude-oil reserves may be thrown into one huge estimate.

We are offering the foregoing classification for criticism and study. If it seems to meet with general approval, we suggest that it be adopted by the industry. If it is not satisfactory, let us, as soon as possible, arrive at a classification that *is* satisfactory, and then let all individuals and organizations adhere to it in presenting estimates of oil reserves. This does not mean that all estimates must include all classes of reserves. It merely means that all estimates must be clearly labelled as to what classes of reserves are included in the figures presented.

THRUST FAULT ON BARRANQUILLA-CARTAGENA HIGHWAY, COLOMBIA[1]

STUART K. CLARK[2]
Ponca City, Oklahoma

The accompanying sketch of a thrust fault in a road cut on the Barranquilla-Cartagena highway, 86 kilometers (53.4 miles) from Barranquilla, Colombia, South America, presents an interesting instance of faulting in which a failure

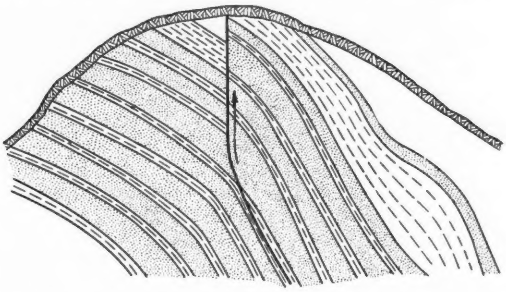

FIG. 1.—Diagrammatic sketch of thrust fault in road cut on Barranquilla-Cartagena highway, Colombia.

initiated as a "reverse diagonal shear" (with reference to the stratified rocks in which it occurs) passes downward into a "bedding plane shear" along the limb of the slight anticlinal flexure which presumably played a part in determining the location at which the initial failure occurred.

It is also interesting because the tilting of the entire mass of strata is such that the upper part of the fault is now almost precisely vertical.

[1] Manuscript received, July 22, 1944.

[2] Continental Oil Company.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

INDEX FOSSILS OF NORTH AMERICA, BY HERVEY W. SHIMER AND ROBERT R. SHROCK

REVIEW BY CHARLES E. DECKER[1]
Norman, Oklahoma

**Index Fossils of North America*, by Hervey W. Shimer and Robert R. Shrock. The Technology Press, Massachusetts Institute of Technology (1944). 837 pp. including 5 figs., 303 pls. with preface, table of contents, and index of genera and species. (Revision and enlargement of 1909 edition.) Distributed by John Wiley and Sons, Inc., New York; Chapman and Hall, Limited, London. Price, $20.00.

First and foremost, it should be said that this book represents an enormous task well done, and appreciation and congratulations are extended to the authors and their collaborators.

Considering the new edition as a revision in which a slight change in the title has been made, a comparison of the two editions is made in tabular form as follows.

	1909–10 Edition	*1944 Edition*
Volumes	Two	One
Size	$5\frac{3}{4} \times 9\frac{1}{4}$ inches	$7\frac{1}{2} \times 10\frac{3}{4}$ inches
Pages	1,762	837
Print	Large	Smaller
Columns	One	Two
Plates	All text figures	303
Separate illustrations	4,295	9,312
Number of species	4,890	7,322
Plants	None	3 plates
Extra material	358 pages	None

In the new edition of less than half the number of pages, the number of species has been increased by 50 per cent and the individual illustrations by more than 100 per cent.

It contains 14 out of the first 100 species listed in R. S. Bassler's "Ordovician and Silurian Bibliographic Index," and 9 species out of 100 listed about the middle of Stuart Weller's "Bibliographic Index of Carboniferous Invertebrates."

The introduction states the purpose and limitations of the work, gives definitions, general references, key to abbreviations, acknowledgments, source of illustrations, and considers authorship, range, and geographic distribution.

In the phylum PROTOZOA, 5 groups are treated. 1. G. D. Hanna gives five reasons why SILICOFLAGELLATA are important as horizon markers. 2. The smaller FORAMINIFERA are treated extensively by J. A. Cushman. Besides a comprehensive statement about them he describes and gives the range for 128 genera, and under each genus lists one or more species with range and distribution. This constitutes more than one-fourth the number in his *Special Research Publication No. 1*. 3. FUSULINIDAE, so important in the Pennsylvanian and Permian, are illustrated by L. G. Henbest in two plates of cross sections and four enlarged text figures. Under 10 genera, he describes in detail 32 species.

[1] Research professor in paleontology, University of Oklahoma. Manuscript received, July 14, 1944.

4. The large ORBITOIDAL FORAMINIFERA, important in Cretaceous and Tertiary in Low Latitudes, are described by W. S. Cole in 8 genera and 17 species. 5. The tiny siliceous RADIOLARIA, known from pre-Cambrian to Recent, are treated briefly by the authors. Occurring only at scattered horizons as fossils, 4,200 recent species have been described.

The phylum PORIFERA, known from Cambrian to recent, is treated under 3 classes and 4 orders with descriptions of 31 genera. Many forms occur in great numbers locally. A few, as *Ischadites*, and *Receptaculites*, have wide distribution. *Archeocyathus* is limited to the Lower Cambrian. A similar form, called *Archaeoscyphia* by field men, occurs widespread in the lower part of the Kindblade formation (Lower Ordovician) in the Arbuckle Mountains and Wichita Mountains. Separate sponge spicules occur in great abundance in some formations.

The phylum COELENTERATA is divided into five classes. 1. HYDROZOA includes the living *Hydra* and the numerous branching marine hydrozoans said to be rarely fossilized, but 19 species have been described from the Middle Cambrian of Australia,[2] and 5 genera in this group were previously described as graptolites. Also under HYDROZOA is the coral-like group of MILLEPORA, important as reef-builders from Triassic to Recent. 2. For STROMATOPOROIDEA, important Paleozoic reef-builders, 13 genera are described and 24 species listed. Figures show details of structure. 3. Under GRAPTOZOA, 31 genera and 75 species are described. This is nearly one-third the genera defined by Bulman.[3] *Didymograptus protobifidus* should be attributed to Elles 1933 instead of to (Hall). 4. SCYPHOZOA includes the large free-swimming jelly fish. These are rare as fossils, and *Brooksella* and *Laotira*, commonly shown in text-books, are not included. However, following Kiderlen,[4] CONULARIDA, commonly classed with the MOLLUSCA, has been placed under SCYPHOZOA. In spite of Kiderlen's evidence from larval forms and those considered to be related groups, the reviewer feels that this change in classification is not justified. Rare as fossils, members of this group have relatively little value for correlation. 5. ANTHOZOA, revised with the assistance of ten paleontologists, Early Ordovician to Recent, includes simple and compound corals with reef-building types developing in the Silurian and Devonian, and continuing important in various periods to the present. Most of 118 genera and part of 230 species are described and illustrated on 24 plates in various views and cross sections.

ECHINODERMA is divided into 2 subphyla, 7 classes, and 4 subclasses. Four of the classes are grouped as attached forms and three as free-moving. 1. CYSTOIDEA, first of the 7 classes, includes the simplest and most primative forms found from Cambrian to Permian. Generally plates of the test are irregular in shape and irregularly arranged. Because they are poorly cemented, plates of the calyx occur separately. These plates may be very numerous and diagnostic for certain horizons, as in the Bromide and McLish formations in the Simpson group of Oklahoma and in the Chazyan of eastern North America. Under 22 described genera, part of 29 species are described. 2. In EDRIOASTEROIDEA, 14 species are listed under 11 genera. The fossils are tiny disc-like bodies attached by their lower surface, and with curved food grooves on the upper surface. They are so rare that they have almost no value for correlation. 3. The class BLASTOIDEA has been revised by L. M. Cline. Occurring from Ordovician to Permian, they became important in Middle Devonian and reached a climax in Upper Mississippian. Twelve genera and 29 species are

[2] F. Chapman and D. E. Thomas, "The Cambrian Hydroida of the Heathcote and Monegeeta Districts," *Proc. Roy. Soc. Victoria*, 48 (N.S.), Pt. II (1936), Art. 15, pp. 193–212, Pls. 14–17.

[3] O. M. B. Bulman, "Graptolithina," *Handbuch der Paläozoologie*, Lief. 2, Bd. 2. Edited by O. H. Schinderwolf (1938), pp. 1–92; 42 figs.

[4] Helmut Kiderlen, "Die Conularien," *Neues Jahrbuch für Mineralogie, Geologie und Palaontologie* Abteil. B (1937), pp. 113–65; 47 figs.

described. 4. The class CRINOIDEA has been extensively treated by R. C. Moore and L. R. Laudon. This follows closely upon their paper[5] on "Evolution and Classification of Paleozoic Crinoids." Besides 21 regular plates, 5 plates show details of plate arrangement and there is one page of illustrations explaining terminology. Under 241 genera, 534 species are illustrated. In Plate 79, diagnostic fragments are illustrated. *Camarocrinus ulrichi* has been shown by Springer[6] to be the bulbous base of *Scyphocrinus* used only for anchorage. Until recently, complete crinoids were considered rare. Crinoids stems frequently make up large parts of some limestones. 5. The class STELLEROIDEA, Cambrian to Recent, includes STAR FISH with 1 genus and 1 species, and SERPENT STARS with 3 species, all are rare. 6. The class ECHINOIDEA is revised with the assistance of H. L. Clark, C. W. Cooke, and L. W. Stephenson. In 4 orders 55 species are illustrated under 35 genera. Occurring from Ordovician to Recent, they are most important in Lower Cretaceous through Tertiary. J. S. Smiser[7] has shown that fragments of the test are diagnostic, 1 species for the Trinity, 6 for the Fredericksburg, and 18 for the Washita. 7. HOLOTHUROIDEA occur from Cambrian to Recent, and became important in the Mississippian and later. Tiny calcareous spicules constitute the fossils. In 3 genera, 5 species are illustrated. They have some value as microfossils.

WORMS.—While four phyla are listed, fossils are preserved in only one, ANNELIDA, as chitinous jaws, calcareous tubes, and borings or trails. Occurring Cambrian to Recent, they are important in some horizons. Treated under 15 genera, some species are listed as diagnostic of Ordovician, Silurian, or Devonian.

CONODONTS.—E. B. Branson and M. G. Mehl have illustrated and given the range for 98 species under 72 genera. Very important as horizon-markers in various formations of the Paleozoic, the tiny jaws are generally well preserved.

BRYOZOA.—This chapter was written with the assistance of R. S. Bassler. They occur from Early Ordovician to Recent. In some places they are so abundant that they constitute the major part of the rocks in which they occur. Under 5 orders 182 species are illustrated in 135 genera, and a number of others are described. Important for widespread correlation, many of them are identified by means of thin sections.

BRACHIOPODA.—This chapter was prepared by G. A. Cooper. Rare in the pre-Cambrian, brachiopods became important for correlation in the Cambrian, and remained the most important group throughout most of the Paleozoic. The magnitude of the task on this group is seen in the description of 301 genera, and in illustrating and describing 519 species, and in listing many more species with their horizons. In addition to 37 regular plates, 2 plates of figures illustrate interior and exterior parts and markings. Occurring only at intervals since the Paleozoic, they have some importance in the Tertiary of Europe, and there are more than 200 living species. Characteristically attached throughout most of their lives, the brachiopods attained wide distribution during their free-moving larval stage. Accordingly, many species are valuable for widespread correlation.

MOLLUSCA.—This is an extremely variable phylum divided into 5 classes, 5 subclasses, 4 superorders, 21 orders, and 5 sections of one order. Generally *Conularida* has been included in this phylum instead of under SCYPHOZOA as noted earlier. The 5 classes are noted separately. 1. PELECYPODA.—The authors acknowledged the assistance of 14 specialists in treating this group. Rare in the Cambrian, this group has many diagnostic

[5] R. C. Moore and L. R. Laudon, "Evolution and Classification of Paleozoic Crinoids," *Geol. Soc. America Spec. Paper 46* (1943), pp. 1–167, Pls. 1–14.

[6] F. Springer, "On the Crinoid Genus Scyphocrinus and Its Bulbous Root Camarocrinus," *Smithsonian Inst. Pub. 2440* (1917), p. 9.

[7] J. S. Smiser, "Echinoid Fragments in the Cretaceous Rocks of Texas," *Jour. Paleon.*, Vol. 7 (1933), pp. 123–63.

species in various horizons from Ordovician to Recent. They are abundant and highly differentiated at present and some are very important for food. In 185 described genera several hundred species are listed with horizon and distribution for each. They are illustrated on 30 plates, the oyster group on Plates 153 to 157, and some aberrant types on Plate 168. They reached their highest development in the Pectens which have been numerous as fossils, and are dominant in the oceans today. 2. GASTROPODA.—This group has been revised with the assistance of J. B. Knight and J. Bridge. Important as fossils from Cambrian to Recent, they are abundant at present in marine and fresh waters and on land. Many diagnostic species occur in various formations, and many of them are distributed widely. Under 278 described genera many hundred species are described with range and distribution. A figure on page 174 shows details of structures, parts, and markings. Illustrations are shown on 39 plates. 3. SCAPHOPODA.—These are small forms with tapering test. Few in the Ordovician, they became abundant in certain formations of the Tertiary and in the Pleistocene of California. *Dentalium* is the most common genus. Similar forms of uncertain position are *Hyolithes* and *Tentaculites* both of which have considerable value as fossils. 4. AMPHINEURA.—Occur rarely as fossils from Ordovician to Recent, so they are treated briefly. 5. CEPHALOPODA.—The names of 13 men are listed as assisting in the revision of this group. This highest division of the MOLLUSCA occurs from Early Ordovician to Recent, those with simple sutures having that entire range, while the AMMONOIDEA with complex sutures occur from Silurian to Cretaceous, and the DIBRANCHIATA Triassic to Recent. There are more than 300 genera and many thousand species in each of the two major groups. About one-third of the total known genera (246) are described here. Many more species are listed, some are described, and for each the range and the numerous localities in which each has been found are given. With their excellent means of locomotion cephalopods could travel long distances in a short time, so species are very widely distributed. The test is well adapted for preservation of the minutest details, and many species had a short time range. Accordingly, they are particularly good fossils for widespread correlation. The Nautiloids, Ammonoids, and Coleoids (Dibranchiates) are all well illustrated.

ARTHROPODA.—This phylum is divided into 5 classes and 11 subclasses. The class CRUSTACEA is divided into 9 subclasses each of which are here noted briefly. 1. AGNOSTIA.—Limited to the Cambrian and Ordovician, this group includes 13 genera of forms with two thoracic segments, usually classed with the TRILOBITA. 2. TRILOBITA.—This is far the most important subclass which is revised with the assistance of ten paleontologists. They range from Cambrian to Permian, and they are most important in the Early and Middle Paleozoic. As these forms had good means of locomotion, they occur widespread. Because they molted periodically, many fragments doubtless represent parts of the discarded tests. In much of the correlation with trilobites only generic determinations are used. They are divided into three groups, those from the Lower and Middle Cambrian with 69 genera described, those from the Upper Cambrian with 69 genera, and those in the post-Cambrian with 79 genera described. Under each genus one or more species are listed with range and distribution. 3–6. HOMOPODA, XENOPODA, ARCHAEOSTRACA, AND BRANCHIOPODA are rare as fossils though some have importance at specific horizons. 7. OSTRACODA.—Nine others assisted the authors in the revision of this group. They occur from Ordovician to Recent, and often in such abundance as to make up a large part of the rocks. Scores of papers have been written on this group lately, and nearly 700 figures are shown here on 13 plates. Some of them have great value in subsurface correlation. 8 and 9. CIRRIPEDIA and MALACOSTRACA are relatively rare as fossils, though abundant at present.

ONYCHOPHORA.—They are not known as fossils.

MYRIAPODA.—They are extremely rare as fossils.

INSECTA.—Prepared by F. M. Carpenter, the article on this class is brief. While the range has been given as Pennsylvanian to Recent, and several thousand species have been described, they have been preserved at scattered horizons under such specialized conditions that they have little value as index fossils.

ARACHNIDA.—This group is known from Cambrian to Recent. It contains a number of interesting Paleozoic forms, the most common of which are the eurypterids, but these are too rare to have much value for correlation. Spiders are recent representatives of the group.

FOSSIL PLANTS.—The authors were assisted by G. D. Hanna, R. E. Peck, and J. H. Johnson in the preparation of this chapter. Only diatoms, charophyta, and calcareous algae are considered.

1. DIATOMS.—Diatoms occur from Cretaceous to Recent, and they were most abundant in the Miocene of California. A few of these tiny siliceous forms are shown on Plate 301. They have some value as microfossils. 2. CHAROPHYTA.—They occur from Devonian to Recent, but are more abundant in the Jurassic and later. While they are numerous in some formations, these tiny fruiting structures are not sufficiently well known to have much value as fossils. 3. CALCAREOUS ALGAE.—They occur from pre-Cambrian to Recent. Only a few are illustrated on Plates 302 and 303 as compared with those listed in the table on page 715. The reviewer has found that some calcareous algae are very helpful in the correlation of Ordovician formations.

This brief chapter is a good start, but several additional plates on fossil plants would be desirable,—one on the more common Pennsylvanian and Permian forms, one on Cretaceous floras, and one on Tertiary floras.

There are two minor omissions. Number 39 is omitted from plate and explanation on pages 448, 449, and 20 is omitted on pages 580, 581.

A summary statement would be that this volume contains a remarkably large number of fossils, well illustrated; briefly, but adequately described; together with range and distribution for each, all in convenient useable form. The authors have placed the stamp of authority on this edition by securing the assistance of about 75 specialists in its preparation.

RECENT PUBLICATIONS

CANADA

*"Geology Promises More Oil Fields in Turner Valley Area," by G. S. Hume. *Oil Weekly*, Vol. 114, No. 4 (June 26, 1944), pp. 32–40; 3 figs.

*"Eastern Canada Presents Oil Possibilities," by L. J. Logan. *Oil Weekly*, Vol. 114, No. 7 (Houston, July 17, 1944), pp. 17–20, 24–26; 2 maps.

*"Petroleum Possibilities North of 'Sixty One'," by H. G. Cochrane. *Oil and Gas Jour.*, Vol. 43, No. 11 (Tulsa, July 22, 1944), pp. 42–44; 3 figs.

COLORADO

"Structure-Contour Map of the Rangely Anticline, Rio Blanco and Moffat Counties, Colorado," by C. R. Thomas *et al. U. S. Geol. Survey Prelim. Map 7*, Oil and Gas Inves. Ser. (June, 1944). Includes graphic section of exposed rocks, description of the geology, and history of drilling and production. For sale by Director, U. S. Geol. Survey, Washington 25, D. C. Price, $0.40.

EAST INDIES

*"Miocene Foraminifera from Sumatra and Java, Netherlands East Indies," by L. W. LeRoy. *Quar. Colorado School Mines*, Vol. 39, No. 3 (Golden, July, 1944). 113 pp., 15 pls. of fossils, 2 figs. Price, $2.00.

GENERAL

*"Correlation of Pennsylvanian Formations of North America," by the Pennsylvanian Subcommittee, R. C. Moore, Chairman; Committee on Stratigraphy of the National Research Council. *Bull. Geol. Soc. America*, Vol. 55, No. 6 (New York, June, 1944), pp. 657–706; 1 pl.

*"Military Geology: Applications of Geology to Terrain Intelligence," by Charles E. Erdmann. *Ibid.*, pp. 783–88.

*"Geologic Use of Drilling-Time Data," by G. Frederick Shepherd and Gordon I. Atwater. *Oil Weekly*, Vol. 114, No. 5 (Houston, July 3, 1944), pp. 17–24; 8 figs.

*"Problems of Terrace Correlation," by Douglas Johnson. *Bull. Geol. Soc. America*, Vol. 55, No. 7 (New York, July, 1944), pp. 793–818; 1 pl., 1 fig.

**Oil and Petroleum Year Book 1944*, compiled by Walter E. Skinner. liv+182 pp. "A record of companies interested in the oil industry (producers, refiners, transporters, dealers, and oil finance) operating in all parts of the world and a list of managers, engineers, agents, *et cetera*." Published by Walter E. Skinner, 20 Copthall Avenue, London, E.C. 2. Cloth. 5.25×8 inches. Price, 12s. 6d. net; abroad, 13s. 6d. net. Post free.

ILLINOIS

"Structure of Herrin (No. 6) Coal Bed in Christian and Montgomery Counties and Adjacent Parts of Fayette, Macon, Sangamon, and Shelby Counties," by J. Norman Payne and Gilbert H. Cady. *Illinois Geol. Survey Cir. 105* (Urbana, July, 1944). Price, $0.50.

KANSAS

*"Stratigraphy and Vertebrate Paleontology of Pleistocene Deposits of Southwestern Kansas," by Claude W. Hibbard, *Bull. Geol. Soc. America*, Vol. 55, No. 6 (New York, June, 1944), pp. 707–54; 3 pls., 20 figs.

*"McLouth Gas and Oil Field, Jefferson and Leavenworth Counties, Kansas," by Wallace Lee and Thomas G. Payne. *Kansas Geol. Survey Bull. 53* (Lawrence, June, 1944). 195 pp., 10 pls., 20 figs., 27 tables.

MISSISSIPPI

*"Monroe County Mineral Resources." Geology by Franklin Earl Vestal. Tests by Thomas Edwin McCutcheon. *Mississippi Geol. Survey Bull. 57* (University, 1943). 218 pp., 14 figs., 5 pls.

MISSISSIPPI-ALABAMA

"Map of Quitman Fault Zone, Clarke and Wayne Counties, Mississippi, and Choctaw County, Alabama," by Harry A. Tourtelot and James H. Morris. *U. S. Geol. Survey Prelim. Map 6*, Oil and Gas Inves. Ser. (June, 1944). Shows differentiation of 10 rock units of early Tertiary age. For sale by Director, U. S. Geol. Survey, Washington 25, D. C. Price, $0.25.

MONTANA

"Map of Oil and Gas Possibilities of the Plains Adjacent to the Little Rocky Mountains, Montana," by M. M. Knechtel, S. R. Brockuneir, and S. W. Hobbs. *U. S. Geol. Survey Prelim. Map 4,* Oil and Gas Inves. Ser. (June, 1944). Scale, 1 inch = 4,000 feet. For sale by Director, U. S. Geol. Survey, Washington 25, D. C. Price, $0.30.

NEW MEXICO

"Stratigraphic Distribution of the Pennsylvanian Fusulinidae in a Part of the Sierra Nacimiento of Sandoval and Rio Arriba Counties, New Mexico," by Lloyd G. Henbest and Charles B. Read. *U. S. Geol. Survey Prelim. Chart 2,* Oil and Gas Inves. Ser. (June, 1944). Graphic sections and text. For sale by Director, U. S. Geol. Survey, Washington 25, D. C. Price, $0.25.

NORTH DAKOTA

*"The Geology and Ground Water Resources of the Emerado Quadrangle," by Wilson M. Laird. *North Dakota Geol. Survey Bull. 17* (Grand Forks, 1944). 34 pp., 7 figs., 3 pls., 6 tables.

OHIO

"Map of the Second Berea Sand in Gallia, Meigs, Athens, Morgan, and Muskingum Counties, Ohio," by J. F. Pepper. *U. S. Geol. Survey Prelim. Map 5,* Oil and Gas Inves. Ser. (June, 1944). Scale, 1 inch = 3 miles. Prepared from logs of 1,000 wells. For sale by Director, U. S. Geol. Survey, Washington 25, D. C. Price, $0.40.

UTAH

*"Geology of the North-Central Wasatch Mountains, Utah," by A. J. Eardley. *Bull. Geol. Soc. America,* Vol. 55, No. 7 (July, 1944), pp. 819–94; 14 pls., 10 figs.

WYOMING

"Map of Oil and Gas Fields of Wyoming," by William G. Pierce, Jane Hanna, and Roselle M. Girard. *U. S. Geol. Survey* (June, 1944). Scale, 1 inch = 8 miles. Includes list of producing formations in 133 fields. For sale by Director, U. S. Geol. Survey, Washington 25, D. C. Price, $0.50.

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

**Journal of Sedimentary Petrology* (Tulsa, Oklahoma), Vol. 14, No. 2 (August, 1944).

"Mechanical Analyses of Some Bottom Deposits of the Northern Red Sea," by N. M. Shukri and R. A. Higazy

"The Mineralogy of Some Bottom Deposits of the Northern Red Sea," by N. M. Shukri and R. A. Higazy

"Heavy Minerals of Colorado River Terraces of Texas," by R. W. Mathis

"Some Structural Differences Between Wind-laid and Water-laid Deposits on the West Shore of Lake Michigan," by O. F. Evans

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MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa 1, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

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REPORT OF MEDAL AWARD COMMITTEE[1]

A. RODGER DENISON[2]
Tulsa, Oklahoma

THE FUND

During the month of May the original goal of the Sidney Powers Memorial Medal Fund was reached. This was made possible by a single contribution of more than $4,000 by E. DeGolyer, internationally known geologist, consultant and adviser to the petroleum industry. The contribution is the fulfillment of a pledge to underwrite the fund, to the extent of half, or $5,000, made on the initiation of the Sidney Powers Memorial Medal Award.

Original announcement of the award and solicitations for the fund were made in June, 1943, and contributions by months are shown in Table I.

TABLE I

During Month	*Contributors*	*Amount*	*Total Cumulative*
June—1943	264	$1,736.50	$1,736.50
July	178	1,628.00	3,364.50
August	36	496.50	3,861.00
September	35	280.50	4,141.50
October	46	294.00	4,390.50
November	71	360.00	4,750.50
December	106	572.75	5,323.50
January—1944	41	354.00	5,677.25
February	19	100.00	5,777.25
March	4	21.50	5,798.75
April	2	8.50	5,807.25

[1] Received, July 17, 1944.
[2] Chairman.

Thus on May 1, eight hundred contributors had sent in $5,807.25. During May Mr. DeGolyer contributed $4,192.75, bringing total contributions to $10,000. After payment of the expenses necessary in connection with executing the design and cutting the die for stamping the medal a little more than $9,300 remained in the fund. This amount has been invested in Series G War Bonds which return interest at the rate of 2½ per cent annually. The income only will be used to purchase the medal.

While the fund has now reached the original goal, it is by no means closed. According to the rules of the award, contributions to the principal sum or to the income from the invested funds can be made at any time. The income from the fund will not be adequate to award a medal until June, 1945, some time beyond the time of the annual meeting. The committee is, then, in need of contributions of any amount, however small, to the income account, to enable them to plan for an earlier presentation of the medal. Such contributions should be sent to the Business Manager, Box 979, Tulsa 1, Oklahoma, and should be clearly designated for the Sidney Powers Memorial Medal Fund, either principal sum or income account.

It is a source of profound satisfaction to the medal award committee and the executive committee that the Sidney Powers Memorial Medal Award now enjoys widespread acceptance by the membership. Contributions were received from more than 20 per cent of our members located in 36 states and one territory of the United States and 12 foreign countries, one of which is in the Eastern Hemisphere. The number received from each state and country is shown in Table II.

TABLE II

Alabama	4	Ohio	8
Arkansas	2	Oklahoma	158
California	84	Pennsylvania	9
Colorado	11	South Dakota	1
Connecticut	2	Texas	222
District of Columbia	24	Utah	2
Florida	2	Virginia	5
Georgia	1	Washington	2
Illinois	44	West Virginia	6
Indiana	10	Wisconsin	1
Kansas	27	Wyoming	1
Kentucky	2	Hawaii	1
Louisiana	34	Foreign Countries	
Maryland	2	Argentina	6
Massachusetts	4	Canada	7
Michigan	12	Chile	1
Minnesota	3	Colombia	5
Mississippi	18	Costa Rica	1
Missouri	5	Cuba	1
Montana	6	Dominican Republic	2
Nebraska	1	Ecuador	3
New Jersey	4	Egypt	3
New Mexico	8	Mexico	4
New York	31	Peru	1
North Carolina	1	Venezuela	8
Total contributions		800	

Every person who made a contribution to the fund, regardless of the size, was sent an acknowledgment. While the committee fully realizes that our financial goal could never have been achieved without the small number of larger contributions, it desires to thank in particular the larger number of small contributors. Only by a widespread interest among a large number of our members can a plan such as this be regarded as successful. The contributors listed according to the amounts given are shown in Table III.

TABLE III

TABULATION OF CONTRIBUTIONS BY AMOUNTS

13	$100.00	$1,300.00
7	50.00	350.00
1	30.00	30.00
29	25.00	725.00
8	20.00	160.00
8	15.00	120.00
1	12.50	12.50
109	10.00	1,090.00
2	7.50	15.00
1	6.00	6.00
213	5.00	1,065.00
3	4.00	12.00
1	4.50	4.50
1	3.50	3.50
39	3.00	117.00
250	2.50	625.00
56	2.00	112.00
3	1.50	4.50
1	1.25	1.25
54	1.00	54.00
	Total	$5,807.25

THE AWARD

The medal award committee after nearly one year of study, analysis, and exchange of ideas is now formulating a set of criteria by which to evaluate the achievements in, and contributions to petroleum geology. With these criteria established, the committee will then proceed to canvass the entire roster of those who may be eligible. Since no award has ever been made for "distinguished achievement in, or contributions to petroleum geology" it is anticipated that a number of persons will qualify. These will then be compared on the basis of their individual records in order to present the first such award to the most outstanding of this selected group.

While it is the sole responsibility of the medal award committee to choose, subject to the approval of the executive committee, the recipient of the award, the committee welcomes ideas, suggestions, and opinions from the membership at large concerning the fund, the award, or any item concerning the rules or regulations which govern their activities.

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Memorial

ROBERT HAMILTON CUYLER
(1908–1944)

Captain Robert Hamilton Cuyler, assistant director of the Army Air Forces, Ground Training Technical Advisory Unit, Central Instructors School, Randolph Field, Texas,

ROBERT HAMILTON CUYLER

was killed in an airplane accident near Blanco, Texas, on March 13, 1944, while on a training mission. Captain Cuyler was associate professor of geology at The University of Texas, having been a member of the faculty of the department of geology for the past 17 years, and was on leave of absence while serving with the Army Air Corps.

Captain Cuyler was born in Austin, Texas, on May 28, 1908, the son of Robert Henry Cuyler and Sarah McBryde Cuyler. In 1911 the Cuyler family moved to North Carolina where they lived for 6 years. In 1917 they returned to Austin, and at the age of 9 years young Cuyler enrolled in the Austin Public Schools. He graduated from High School at the age of 15 and entered The University of Texas, completing the course for the B.A. degree in 3 years, and was graduated in June, 1926. He continued in the graduate school at The University of Texas and received the degree of Master of Arts in 1927 (thesis: "Georgetown Formation of Central Texas and Its North Texas Equivalents," see Bibliography), and the degree of Doctor of Philosophy in 1931, at the age of 23. His dissertation for the doctorate was "Travis Peak Formation of Central Texas."

Cuyler was appointed to an instructorship in the department of geology in 1927, after having served as a student assistant during his undergraduate days. He was continuously a member of the faculty from that time until his death. In 1935 he was advanced to the rank of assistant professor and in 1939 was promoted to an associate professorship.

Captain Cuyler's chief interest was in micropaleontology and subsurface geology, and he developed outstanding courses in these branches of geology. With an unusual capacity for organization he scheduled the subject-matter for his courses in minute detail, usually passing out a mimeographed outline for the full semester's work, on the first day of class. Setting a high standard for his own work, he was not content to do anything in a makeshift fashion. Everything was done thoroughly and completely, even to the smallest detail. He instilled the same feeling in his students and insisted that everything that they turned in should represent their best effort. He would frequently inquire of a student who was handing in an assignment if he were willing "for me to show this to a prospective employer as a sample of your work?" His enthusiasm, a rare quality in a teacher, was infectious and his students worked willingly and eagerly on his courses. His success and popularity as a teacher are attested by the large enrollment in his classes and the number of successful geologists whose interest in the science was due to his inspiration. With an outstanding memory for names and faces he could recall the full name, home town, and other details of hundreds of students years after they had graduated. He frequently astonished his classes by calling each member by their full name on the second meeting of the class. Many of his students became personal friends, and he followed their work closely after they left school. In the supervision of graduate work he gave unsparingly of his time, and not infrequently he spent Sundays, holidays, and long hours at night working with students. Always punctual to the second in appointments, he liked to schedule his work weeks ahead and frequently would make appointments with students for 11 or 12 o'clock at night, after both had attended some function earlier in the evening.

Captain's Cuyler's work required a close knowledge of the oil industry, and he kept informed to a remarkable degree on the activities in the various parts of the country. He spent a number of vacations actively working in the oil industry, a field in which he was unusually successful. In his most recent work in the oil industry he was associated with John F. Camp, of San Antonio. This association was most enjoyable and resulted in one of the closest friendships of his life.

He was also interested in field work and for many years assisted in teaching the summer field course in geology offered by The University of Texas. In the field he displayed the same energy and capacity for work which he had in the laboratory and set an example which inspired the students to put forth their best efforts. In addition to his interest in geology, Cuyler was well informed in botany, especially field botany, which he used to advantage in his field studies.

For some years Captain Cuyler had supervised thesis problems for the Master's degree and dissertations for the Doctor's degree. Students working on subsurface problems were frequently faced with the task of spending months assembling the essential information from widely scattered sources.

Early in 1940, Cuyler submitted through The University of Texas a proposal to the Works Progress Administration for a project to make copies of all logs and other subsurface data on wells drilled in Texas. This material was to be used as a source of information for subsurface studies and as a permanent reference collection. The "Well Logging Project" was approved, and, under the direct supervision of Cuyler, work was started on September 25, 1940, at Houston, Texas. The project ran for 2 years and employed an average of about 125 persons per day. The project included the preparation of a card for each well drilled in Texas, giving all pertinent data available on the well. In addition, a collection of sample and paleontologic logs, a collection of plotted driller-logs, and a collection of electrical logs were assembled. Altogether, 120,000 plotted driller's logs, 10,500 electrical logs, and several thousand sample logs are in the collection. These are filed in a permanent collection at The University of Texas. This collection, together with several million well samples, many of which Cuyler was instrumental in obtaining, represent an accumulation of subsurface data invaluable in teaching and research. Although Cuyler left The University to enter the Army before the final completion of this project, the collection will be a monument to his farsighted wisdom and tireless energy in working out the details and carrying on the project in addition to a full teaching schedule.

Captain Cuyler was married to Esther Arsinoé Solcher, a college classmate, of San Antonio, Texas, on November 9, 1927. Mrs. Cuyler received the Ph.D. degree in botany and taught in the department of botany for several years after their marriage. "Bob" and "Esther," as they were affectionately known by their host of friends, were ideally happy and Esther proved an invaluable helpmate for her husband—working by his side and with equal efficiency. Their only child, a son, was born just one month before his father's death.

Captain Cuyler entered the Army Air Forces in July, 1942, as a First Lieutenant, and was promoted to Captain on October 18, 1943. After he had completed training at the Officers Training School at San Antonio Aviation Cadet Center, on August 15, 1942, he was placed in charge of the maps, charts, and aerial photographs course in the Supervision Section of the Pre-Flight School at San Antonio Aviation Cadet Center. On February 1, 1943, when the Central Instructors School, Randolph Field, Texas, was set up, Captain Cuyler was transferred to the Ground School instructors course unit, in charge of the maps, charts, and aerial photographs department. He was made assistant director of the Ground School instructors course, October 5, 1943. When this was merged into the newly organized Ground Training Technical Advisory Unit, Captain Cuyler was appointed assistant director. His handbook and workbook on *Maps, Charts, and Aerial Photographs* has been acclaimed an outstanding contribution to the training of pilots.

Although Cuyler was relatively young in years, he had already distinguished himself in the field of science, as is attested by his election to membership in various learned societies and to positions of trust in these organizations. He was a member of Sigma Gamma Epsilon (honorary geologic fraternity) and a past-president of the local chapter. He became a member of the American Association of Petroleum Geologists in 1929 and was elected a Fellow of the Geological Society of America in 1939. He was also a member of Sigma Xi (president of the Texas chapter, 1936), the Paleontological Society of America, Society of Economic Paleontologists and Mineralogists, Southwestern Geological Society (president, 1928), University Science Club (president, 1933), and the Texas Academy of Science. He was listed in the 1938 edition of *American Men of Science.* He belonged to the Presbyterian Church and was a Mason.

He is survived by his wife, Dr. Esther S. Cuyler, and an infant son, Robert Hamilton Cuyler, Jr., by his mother, Mrs. Sarah Cuyler, one sister, Dr. Iona Hamlet of Fort Wayne, Indiana, and one brother, Dr. William Kenneth Cuyler, Duke University, Durham, North Carolina.

To his many friends who loved him, Cuyler was an outstanding example of a man with high ideals,—gracious, generous, and considerate to the extreme. To his colleagues on the

University faculty his untimely death, in the prime of his career, was a staggering blow. His death is not only a great loss to his wife, son, and relatives, but to all who knew him and to the science of geology. Captain Cuyler's chief monument is his students. Those who studied under him have gone out to oil companies throughout Texas, as well as many other parts of the world. In them, and in the hearts of his friends, he still lives.

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FRED M. BULLARD

THE UNIVERSITY OF TEXAS
AUSTIN, TEXAS
June 22, 1944

JOSEPH ALEXANDER TAFF
(1862–1944)

J. A. Taff was one of those pioneer geologists whose excellent work in stratigraphy and structure laid the foundations of geologic knowledge in the area of his studies for all who might follow him. A Tennessean by birth and a student at the State universities of Arkansas and Texas, he began his geologic field work on the surveys of those States and became a member of the United States Geological Survey in 1894. After several years' work in the coal fields of West Virginia, he was assigned to surveys of similar fields in Arkansas and adjacent areas, where he worked effectively on the stratigraphy of the Paleozoic formations and the structures of the Arbuckle and Wichita mountains. In 1905, he executed surveys of the Book Cliffs field in Utah and in following years also of areas in Wyoming. His investigations included the occurrences of ozokerite in Utah and of grahamite in Arkansas and led on to examinations of the possibilities in oil and gas. Thus his interest was directed to the class of work that was to occupy his attention during the major part of his career. In 1909 he became geologist to the Southern Pacific Railroad and continued with that organization and its Associated Oil Company, of which he was chief geologist from 1921 to 1929, until his retirement in 1937 at the age of 75.

Taff's life as a geologist covered half a century, during which he used the methods of scientific investigation soundly to advance knowledge of the fields in which he worked and to promote the development of the related economic resources. The 15 years on the United States Geological Survey were in the nature of the case the more fruitful in publication, but he demonstrated his continued interest in geologic research by his later con-

tributions, especially by those on the Mount Diablo region, California (1935), and the type locality of the Cretaceous Chico formation (1940).

As a fellow worker, Taff was always coöperative. He accepted cheerfully any assign-

J. A. TAFF, with his wheelbarrow-type odometer and compass, in 1886.

ment of field or office work and carried out his tasks efficiently and thoroughly. He and I were colleagues during a decade, and I came to rely upon him unquestioningly.

Much of the area in which he worked was little known Indian country; there were to begin with no maps; the geology had been sketched only in outline. But he was all that a good field geologist of those days had to be. He was tough, wiry, tireless; could ride a

horse, handle a mule, drive a buckboard anywhere a team could pull it. He was always cheerful, and his sense of humor carried him over many rough places.

I recall a trip into a rather inaccessible area in the mountains of West Virginia. He

J. A. TAFF, in 1933.

and I struck out afoot, our packs on our backs. By mutual agreement he was chopper, I cook. At our first camp, after a long day, he was vigorously swinging his ax when I discovered that baking powder and lard had been left behind. I substituted sugar to raise my

dough, baked the biscuits, and served them without comment. Taff tried a bite and, drawing out his hammer, remarked: "Fossils, new species." We ate fossil cookies for 10 days, but he never kicked.

Taff's earliest publications comprised reports on the Cretaceous of Texas. They appeared in the *Annals* (1891–1893). As a contributor to the publications of the United States Geological Survey, he prepared special articles and folios of the Geologic Atlas of the United States in accordance with the established procedure of the organization, but always with that thoroughness, simplicity of expression, and directness, which were characteristic of the man. His principal work in the southwestern field relates to the geology of the Arbuckle and Wichita mountains, *Professional Paper 31* (1904).

In transferring his activities to the Pacific coast, Taff experienced a complete change of scene. In stratigraphy and structure, his major subjects, the oil fields of California present very different aspects from those with which he had been familiar. The new duties brought also heavy responsibilities of an economic nature. That he was able successfully to meet them was due to his established habit of observing and recording the exact facts and basing conclusions simply upon them. He was no theorist.

He has left a record of his procedure (*G.S.A. Bull.*, Vol. 46 (1936), page 2043), which we may well quote as a guide to others, as well as for the light it throws upon his methods.

(1) Establish the sequence of the sedimentary series, the mappable formations or lithologic units and the age of same, as far as practicable, by preliminary surveys if it has not already been accomplished. The exact age of the formation, zone, or lithologic unit at this stage of the work is not of vital importance providing the order of sequence of sedimentary beds is established.
(2) Assemble or formulate all possible hypothetical or theoretical structural problems as working hypotheses to be proven or abandoned in the progress of the more detailed mapping.
(3) Proceed to locate by areal geologic surveys and place upon an accurate base map all contacts between mappable formations, zones or strata, or lithologic units, noting at the same time the attitude of the outcropping strata, as frequently as practicable, and, in the progress of the work, collect and note the stratigraphic position of the fossils. As the areal surveys progress, keep continually in mind and check all formulated working hypotheses.

Regarding Mr. Taff's work in California, C. C. Church, of the Tide Water Associated Oil Company, contributes the following.

Mr. Taff came to California in 1909 at the invitation of E. T. Dumble, at that time the director of all geologic work for the Southern Pacific Company. Mr. Taff had worked with Dumble on the old Texas Survey before joining the staff of the United States Geological Survey, so his ability was well known and appreciated by the older man.

When Mr. Taff came to California, Josiah Owen, the veteran geologist and long-time associate of Dumble, had been in charge of geological work for the land department, along with Dr. F. M. Anderson, and these two men were the first to acquaint him with his new job. The work was similar to that done on the United States Geological Survey, but the approach and objective were different. The lands of the Southern Pacific had to be classified, surveyed, and appraised with reference to their mineral and petroleum deposits. The territory involved included California, Utah, Nevada, Arizona, and New Mexico. The job also included the conduct of petroleum engineering for the Southern Pacific and subsidiary companies.

At this time and later, both Mr. Taff and Doctor Anderson were referred to or addressed by the title of "Professor," and their contemporaries living to-day still refer to them in that way.

When the Pacific Oil Company was set up as an independent organization, formed to care for the oil properties of the Southern Pacific Company in 1920, Mr. Taff continued as geologist for the new oil company, and since the Southern Pacific had long held a controlling interest in the Associated Oil Company, he also became chief geologist for that company. This latter position he held until 1929. In 1932, he retired as consulting geologist for the Southern Pacific in accord with age-retirement regulations of the company. He con-

tinued as consulting geologist for the Associated Oil Company until September, 1937, when he retired altogether from active work in the company.

In the years between 1909 and 1929, Mr. Taff did very little writing for publication, but he followed the progress of geology very closely. He was usually present at the more important meetings on geology and occasionally took part by reading a paper or in discussion of others. He read widely but aside from this, most of his time was devoted to company work. He did find time for some research and writing and was author or joint author of six short papers on California geology. Two of these have been mentioned. The first paper, on "Age and Correlation of the Moreno Shale" with G. D. Hanna, was published in the *Bulletin* of the American Association of Petroleum Geologists (1926); the next, also with G. D. Hanna, on "A Geologic Section in the Center of the San Joaquin Valley, California," published in the *Proceedings* of the California Academy of Science 4th Ser., Vol. XVII, No. 16, pp. 509–515, has been overlooked in some bibliographies but is often referred to; the next is on the "Geology of McKittrick Oil Field . . . " in the *Bulletin* of the A.A.P.G. (1933); the last is on the "Physical Properties of Petroleum in California," in the Sidney Powers memorial volume of the American Association of Petroleum Geologists (1934).

Mr. Taff was an active supporter of many of the societies related to his profession and laughingly said of himself that he was something of a "jiner." He was a member of the Geological Society of Washington, the American Association for the Advancement of Science, the American Institute of Mining and Metallurgical Engineers, the California Academy of Science, honorary member of the American Association of Petroleum Geologists, and fellow of the Geological Society of America. Apart from the duties of his profession, he was an active supporter of the Episcopal Church of Palo Alto and for many years was a member of the school board.

On the personal side, Mr. Taff was modest and retiring, but in defense of a principle he was fearless and emphatic. A man of quiet sincerity and simple personal charm, an outstanding characteristic was his unfailing sense of humor. He liked a good joke and had a fund of stories dating back to his early years in the survey when transportation depended largely on mules, which he preferred to horses, saying that "mules were more surefooted and smarter." One mule in particular, he liked to remember, was above average in intelligence. This mule, "old Jim," would open gates, turn on water faucets, *et cetera*, but was most useful in the field as a saddle mule. If the tired geologist was uncertain of the direction of camp after a long day chasing an outcrop, he would mount his mule and slowly wheel him in a circle, all the time watching his long ears; when the mule's ears stood up to attention, the rider knew they were "on the beam" and headed for camp.

Mr. Taff's health failed very perceptibly after 1937. He passed away just after 12 midnight, March 9, 1944. Surviving him are his wife, Mary Leverett, daughters Elizabeth Dennison, Mary Willis Moore, Rose, and a son, Joseph Whitham. One son, Leverett, had preceded him in death.

A more complete account of Mr. Taff's family and origin may be found in the *Encyclopedia of American Biography* (1935), and briefer accounts are to be found in *American Men of Science* and in Volume 16 (1930–1931) of *Who's Who in America.*

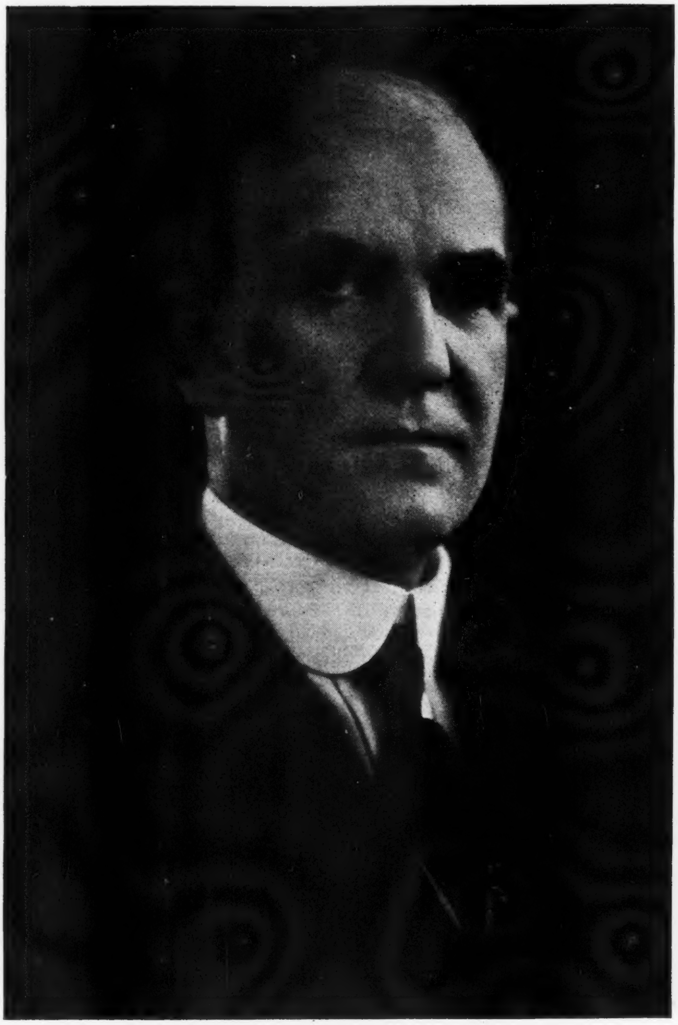
BAILEY WILLIS and C. C. CHURCH

STANFORD UNIVERSITY AND SAN FRANCISCO, CALIFORNIA

July 7, 1944

HENRY ANDREW BUEHLER
(1876–1944)

The sudden death of Dr. H. A. (Chief) Buehler, on March 14, 1944, in his hotel room in Jefferson City, came as a great shock to his many friends and acquaintances. For several



HENRY ANDREW BUEHLER

months he had been suffering from a cold which he was unable to completely overcome and which at times forced him to take time out for rest, but he had felt well enough to attend the A.I.M.E. meeting in New York and the State geologists' meeting in Washington, immediately afterward, during the latter part of February. Upon his return to Rolla he seemed to feel better and could be found in his office every day as usual.

On March 8, he went to Jefferson City to attend a 2-day session of the Missouri Re-

sources and Development Committee and, in order to avoid extra travel and also to get some needed rest, decided to stay there until the meeting of the State Highway Commission on the fourteenth. The day before this meeting, he became worried about a pain in his chest and decided to go to St. Luke's hospital in St. Louis, for a check-up. However, he was unable to obtain accommodations and upon advice of Carl Brown, chief engineer of the Highway Department, he consulted Dr. Enloe, a Jefferson City physician. Later that same day in communication with the Rolla office he said that the doctor had found nothing wrong; that he was feeling better and planned to have dinner that evening with members of the Highway Commission. After dinner they talked for a while and at about 10:30, Chief left, remarking that he felt fine and would see them in the morning. At about 3 o'clock the next morning he became ill and called Dr. Enloe who came immediately and remained until the end which came at 5 o'clock.

Funeral services were held in Rolla on March 16, in the Missouri School of Mines Auditorium. Governor Forrest C. Donnell gave an excellent eulogy and R. C. Allen, a close friend since college days, spoke briefly of the more intimate and personal side of the Chief's life.

Henry Andrew Buehler was born in Monroe, Wisconsin, May 27, 1876. After his preliminary schooling, presumably in the local schools, he entered the University of Wisconsin, graduating from there in 1901 with a degree in chemistry. While attending the University, he became intimately acquainted with Dr. E. R. Buckley, then State geologist of Wisconsin and when Buckley was appointed State geologist of Missouri in 1901, Buehler accepted a position as chemist on the staff at Rolla. Under Buckley's guidance he soon became interested in geology and by 1904 had worked his way up to the position of assistant State geologist.

In 1907 he resigned this position to accept employment as geologist with the Federal Lead Company of Flat River, Missouri. In May, 1908, after a year of service in this capacity, he returned to Rolla to become State geologist in place of Dr. Buckley, who had resigned in April of that year. From that time until the day of his death he was State geologist and director of the Geological Survey, having been reappointed to the position successively by each of nine governors of Missouri.

Throughout this period of nearly 36 years Chief Buehler was on the job continuously except for two short periods when he was on leave of absence. The first of these was occasioned by World War I, when he was active on the War Minerals Board with headquarters in Washington and the second came during the depression period when he served as State engineer for the Missouri Relief and Reconstruction Commission.

Dr. Buehler's record as State geologist speaks for itself. It is impossible, in the scope of this brief memorial, to call attention to all the things he accomplished, or to do justice to even a very small part of them. The Chief lived a full life and his activities were so numerous and varied that one person could not know all of them. Although his prime interest always was in the mineral industry, his broad experience, his constant study and thought, qualified him as prominent authority on a multitude of subjects and activities far removed from this field. Not the least of his outside activity was his interest in civic affairs and the welfare of the community and even more outstanding, his interest in the young men with whom he came in contact on the campus of the School of Mines. How many of these students he helped either financially or with kindly words of advice will never be known but he considered himself well repaid if even a single young fellow was enabled to make the grade and continue to a useful career.

The Missouri Survey, under his administration, has been an example of successful coöperation, not only with the United States Geological Survey and the United States Bureau of Mines, but also with many State surveys and local Missouri activities and organizations. To mention just a few of these, we may call attention to the State Highway Commission, of which the State geologist was ex-officio member; the Resources and

Development Committee; the Well Drillers Association; the St. Louis Section of the A.I.M.E.; the Missouri Mineral Industries Conference. Under Buehler's guidance the Missouri Survey rose to a place of prominence among State geological surveys and served as a pattern for others to follow.

Dr. Buehler was particularly interested in developing the resources of Missouri and much of his effort was expended in that direction. He devised and encouraged new methods and new practices in keeping with this objective and so we find that there was developed in the Survey laboratory the insoluble residue method of correlating stratigraphic horizons, which has done much in the successful application of the knowledge of geology to the location of water wells in all parts of the state and has been extended to correlation problems all over the country. Under his direction, the Missouri Survey was one of the first to take up the various geophysical methods of exploration and to-day there is a wealth of information available in the office files and several geophysical maps have been published.

His intense interest in the development of the natural resources of the state is further evidenced by his efforts to develop water power. The water resources branch of the Survey was organized under coöperative agreement with the United States Geological Survey and has done invaluable work in this field. Again, when the oil industry became interested in northwest Missouri, Buehler immediately made available to all responsible parties such information as the Survey possessed and which was not confidential, but he was ever on the alert to prevent exploitation of the people by unscrupulous promoters.

Throughout all of his activities, both personal and public, he was dominated by a desire to do the most good for the greatest number of people. His work with the Highway Commission was a continuous effort to locate roads where they would do the greatest good and where they would serve the greatest number of taxpayers, and where they would contribute to the welfare and comfort of the largest number of communities and organizations. During the years of severe drouth in Missouri, he kept several field parties continuously at work giving assistance to individuals and communities in their problems of finding adequate water supplies.

Although his interests were centered very largely in Missouri, Chief Buehler 'ong ago became a figure of national prominence in the American Institute of Mining Engineers. He served this organization in various capacities which were climaxed in 1935 by election as president. His service as president was outstandingly characterized by his efforts to build up the membership from the younger men in the profession. His slogan was, "The leaders of the future are the youngsters of to-day." He was greatly interested in the expansion of the affiliated student organizations which would eventually furnish a steady flow of new members for the parent society. After his retirement as president he continued to serve on the board of directors and kept up his active interest in the welfare of the organization.

Because the duties of the office of State geologist allowed little time for other investigations, Chief's contributions to the literature of geology are not as voluminous as are those of some others. Several volumes of the Survey bear his name as author and the administrative reports were largely prepared by him, but his technical writings are limited to his early years, before he became State geologist. With his appointment as State geologist, he became an administrator and executive and had to be content with directing the research activities of others, although from time to time he still prepared articles dealing with the mineral resources of the state.

Chief Buehler had a remarkable capacity for getting acquainted and making friends. His immense frame, his deep, well rounded voice, his hearty, booming laugh, and his conspicuous black felt hat made him an unforgettable figure. He had a charming personality and his speech was so sincere that he easily but without intent, dominated most gatherings. It was not his idea to monopolize the conversation but rather to let others express their views and then after careful analysis, support what seemed to him the most logical view

and add his own thought to what had been presented. He was impatient with and intolerant of carelessness and stupidity but truly sympathetic with honest effort and never failed to lend encouragement to those who worked hard. He worked hard and put in long hours himself and expected his men to do likewise. On field trips he was usually the first to be ready and if during the course of a strenuous day, some may have felt like grumbling or complaining, the Chief's fine sense of humor usually turned the occasion to one of hearty laughter, with a witty remark or a good joke well told.

It was my privilege to have known Dr. Buehler rather intimately for some thirty years during which time I worked for him several field seasons. When I first met him, in 1914, in Ste. Genevieve County, he was already known as Chief Buehler. I think he rather enjoyed the appellation, not because of any vanity, but because of the expression of respect which it implied. He himself had great respect for others and this token of respect touched a responsive chord. The work that summer was hard and the weather and living conditions made it more so, but his interest in our comfort and welfare made the name seem doubly appropriate, reminding me of the tribal chief, solicitous of the welfare of his people. To those of us who knew him best there was only one Chief. Others may use the name in one way or another in their own organizations, possibly as an abbreviation of Chief geologist, without thought of imitation, but to us Chief will always mean Chief Buehler. Next to his title as Chief, I think he appreciated his title of Doctor of Science. He was not the one to set much store by mere titles and degrees, but when in 1925, the Missouri School of Mines awarded him the degree of Doctor of Science, Honoris Causa, in appreciation of his professional work and his loyal support and untiring efforts in behalf of the School, he was deeply touched. Years later from remarks he made to me at odd times, it became apparent how much he really appreciated the honor.

The Chief has passed on, but what he has done and what he stood for will live forever in the memories of those who knew him and those who will come to know of him.

GARRETT A. MUILENBURG

ROLLA, MISSOURI
July, 1944

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BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 28, NO. 8 (AUGUST, 1944), PP. 1245-1248

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

FRANK V. STEVENSON has gone to Ecuador for the International Petroleum Company, Ltd., for the next 2 years. His address is Box 803, Guayaquil, Ecuador.

WALLACE W. HAGAN, who has been employed by the Indiana State Geological Survey for the past 2 years as geologist, has accepted employment with the Tide Water Associated Oil Company at Tulsa, Oklahoma.

K. C. FORCADE has left the Phillips Petroleum Company and is in consulting work at 628 First National Bank Building, Denver, Colorado.

GERALD F. LOUGHLIN, for the past 9 years chief geologist of the Geological Survey, United States Department of the Interior, has accepted an appointment to the newly created position of special scientist in the Survey, and has been relieved of administrative duties in order to devote himself to research on special problems in the field of economic geology. WILMOT H. BRADLEY, for the past 2 years in charge of the military geology unit of the Geologic Branch, has been appointed his successor as chief geologist.

WILLIAM R. SYPE, who has been with the C. H. Frost Gravimetric Surveys for the past year, is now in the employ of the Stanolind Oil and Gas Company, Tulsa, Oklahoma.

DON L. CARROLL has been promoted to associate editor of the *Oil Weekly*. He is editorial representative in New York where he can advantageously cover foreign developments. Carroll has been a district editor, at Houston, during the past year. His new address is Gulf Publishing Company, 250 Park Avenue, New York 17, N. Y.

JOHN G. DOUGLAS, of the Mene Grande Oil Company, has been transferred from Maracaibo to Caracas, Apartado 709, Venezuela.

CECIL D. ROBINSON has resigned his position as district geologist for the Arkansas Fuel Oil Company and has accepted the position of chief geologist of Coastal Refineries, Inc., Commercial Building, McAllen, Texas.

OSCAR R. CHAMPION, formerly district geologist for the Seaboard Oil Company at Midland, is now division manager of the Alder Petroleum Corporation at Fort Worth, Texas. SURCE J. TAYLOR, with the Seaboard at Dallas, succeeds Champion at Midland.

W. FARRIN HOOVER is with the Stanolind Oil and Gas Company as geologist at Lake Charles, Louisiana.

W. E. WRATHER, director of the United States Geological Survey, Washington, D. C., spent part of June and July in the field, keeping in touch with the various activities and attending local conferences.

WALTER H. SPEARS, general superintendent of the land, geological, and mapping departments of the Union Producing Company, was elected vice-president at a recent meet-

ing of the board of directors at Shreveport, Louisiana. Spears was president of the Shreveport Geological Society during the past year.

WILLARD F. BAILEY, recently district geologist for the Skelly Oil Company at Midland, Texas, has been promoted to division geologist of the new division of the Permian Basin and the Texas Panhandle, with headquarters at Tulsa, Oklahoma. C. B. STEINBERGER is district geologist in West Texas, and C. STUART NOLAND is district geologist in New Mexico.

PAUL E. M. PURCELL, recently with the British-American Oil Producing Company at Casper, Wyoming, is now in the employ of the Universal Exploration Company at Casper.

CECIL HAGAN, consulting geologist of Houston, was recently made squadron commander of the training squadron at the United States Naval Air Station at Dallas, Texas.

JOHN H. BEACH, formerly geologist with the Shell Oil Company, Inc., is directing geological work for the Independent Exploration Company, Kern County Land Company Building, Bakersfield, California.

ARTHUR S. HUEY, of the Shell Oil Company, Inc., has been transferred from Casper, Wyoming, to the Bakersfield, California, office of the company.

ROBERT WESLEY BROWN, of Canton, New York, is with the geological division of the Cooperative Refinery Association, 511 Pickwick Building, Kansas City, Missouri.

PAUL H. BOOTS, of Pittsburgh, Pennsylvania, is with the Colombian Gulf Oil Company, Bogota, Colombia.

EDWARD A. KOESTER, long connected with the Darby Petroleum Corporation, is now vice-president of Darby and Bothwell, Inc., 612 Orpheum Building, Wichita, Kansas.

R. MAURICE TRIPP is assistant to ROLAND F. BEERS, president of the Geotechnical Corporation, at Cambridge, Massachusetts.

FRED MCDANIEL, formerly with the Cities Service Oil Company, is with the Sunray Oil Corporation as division engineer at Great Bend, Kansas.

G. F. KAUFMANN has been transferred from the Creole Petroleum Corporation at Caracas, Venezuela, to the Standard Oil Company of Cuba, Havana, Cuba.

L. H. MORRIS, formerly in the geological department of The Texas Company, is employed as district geologist in charge of the Mississippi area for the J. S. Abercrombie Company, Houston, Texas.

V. C. ILLING, of the Royal School of Mines of London, England, made a business trip to Tulsa, Dallas, and Houston during July.

J. H. DERDEN, independent geologist of San Antonio, Texas, since 1934, died on June 16, at the age of 54 years.

M. T. HARTWELL has left the Buffalo Oil Company to take charge of the new geological headquarters of the Snowden and McSweeney Company, Midland, Texas.

WILLIAM J. HENDY, JR., is in the employ of the Stanolind Oil and Gas Company, Jackson, Mississippi.

WILLARD O. HILTON is with the Kansas State Board of Health.

ROBERT S. BREITENSTEIN has changed his address from Buenos Aires, Argentina, to 2501 Albion Street, Denver, Colorado.

R. Stanley Beck has left the Richfield Oil Company to open a paleontology laboratory, specializing in consulting micropaleontology. His address is El Tejon Hotel Building, Room 3, Bakersfield, California.

John Paul Gries, recently teaching at the South Dakota School of Mines, has joined the Magnolia Petroleum Company at the Midland, Texas, district office.

The following annual conventions previously scheduled for dates in the latter part of 1944 have been cancelled at the request of the Office of Defense Transportation, in recognition of the urgent need for conservation of all possible travel facilities in this country for the use of military and essential war-connected traffic: American Petroleum Institute, Chicago, November 13–16, and Independent Petroleum Association of America, Dallas, October 23–25.

Paul K. Sims has left the Metals Section of the United States Geological Survey to accept a commission in the United States Naval Reserve. His address is Ensign Paul K. Sims, 121½ South Main, Petersburg, Illinois.

J. P. Gallagher has moved from Ecuador. His address is Standard Oil Company of Cuba, Apartado 1303, Havana, Cuba.

Ray E. Claiborne, who has been in charge of the Tulsa field office of the Securities and Exchange Commission for several years, is now with the Ambassador Oil Company, Fort Worth National Bank Building, Fort Worth, Texas.

Guard S. Marvin is chief geologist and petroleum engineer with the Allied Oil Company and Central Pipe Line Company, Salem, Illinois.

Homer H. Luttrell is an independent producer at Effingham, Illinois.

Ellis A. Hall is president of the Condor Petroleum Company, Abilene, Texas.

Joseph M. Dawson is engaged in consulting geology and operation, 1802 Tower Building, Jackson, Mississippi.

Lieutenant John B. Lucke, U.S.N.R., has been assigned to the School of Photographic Interpretation, United States Naval Air Station, Anacostia, D. C. He may be addressed there until October 1.

Robert F. Meyer, formerly with the Darby Petroleum Corporation at Wichita, Kansas, is on the staff of the Kerlyn Oil Company and is working out of Lander, Wyoming, this summer.

Thomas N. Roberts has been transferred by the British-American Oil Producing Company from Wichita, Kansas, to Billings, Montana.

Jack H. Heathman has left the Bridgeport Oil Company to go into partnership with W. N. Bartlett and Loren I. Crum at Wichita, Kansas.

M. F. Pryor, formerly with the Darby Petroleum Corporation, is now geologist for Black and Marshall at Great Bend, Kansas.

Frank Bowser has resigned as manager of the Wichita office of Lion Oil Refining Company to accept the position as district geologist in Wichita with the Sunray.

Jack M. Copass has been transferred to Tulsa by the Amerada Petroleum Corporation and his position as district geologist has been filled by C. R. Sullivan.

GLEN C. WOOLLEY, recently of Wichita, Kansas, is opening an office in Jackson, Mississippi, for the Transwestern Oil Company and his place has been filled by FRANCIS E. METTNER.

VICTOR F. REISERER has left the National Refining Company to join the geological department of the Superior Oil Company at Wichita.

LELAND W. JONES, district geologist for the Anderson-Pritchard Oil Corporation at Colorado City, Texas, has been transferred to the Wichita office.

JOHN P. SMITH has been transferred from Wichita to a district job for Carter in Illinois-Indiana, but I do not know his address.

RICHARD L. ROBERTS is in the geological department of Vickers Petroleum Company at Wichita.

ARNOLD S. BUNTE, chief geologist of the Vickers Petroleum Company, is now working out of Roswell, New Mexico.

HAROLD E. MCNEILL, chief geologist of Great Lakes Carbon Corporation at Wichita, has resigned to open an office in that city for the Mercury Drilling Company.

H. B. FUQUA, chief geologist for the Gulf Oil Corporation at Fort Worth, Texas, has been appointed assistant to Joseph H. Russell, vice-president in charge of production: He will move to Houston. H. M. BAYER, zone geologist at Midland, Texas, succeeds Fuqua as chief geologist at Forth Worth. W. J. HILSEWECK is transferred from Fort Worth to Midland as zone geologist.

R. B. PAXSON, formerly with the Superior Oil Corporation at Houston, is chief geologist for the Sunray Oil Corporation at Tulsa.

LOUIS N. WATERFALL, assistant chief geologist for the Union Oil Company of California, has been appointed head of the department succeeding EARL B. NOBLE, who is now in charge of all outside exploration.

ADDISON YOUNG, formerly consulting geologist at Midland, Texas, is research geologist for the Phillips Petroleum Company at Midland.

ARTHUR WADE, of the Shell (Queensland) Development Pty. Ltd., Brisbane, Australia, has been temporarily released under war conditions to join the United States Army Engineering Intelligence Section.

The Pure Oil News of August prints the statement that the picture of IRA H. CRAM, on the cover page of the December, 1943, issue of the *News* is reported to be decorating the wall of a native tailor's shop somewhere in India. Small world!

T. C. HOKE has left the Fain Drilling Company to go with the British-American Oil Producing Company at Tulsa.

JOSIAH TAYLOR has left the Department of Terrestrial Magnetism at Washington, D. C., and has returned to the General Geophysical Company, 2514 Gulf Building, Houston, Texas, to be supervisor of interpretations.

J. SMITH ADAIR has been added to the geological department of the Lion Oil Refining Company, El Dorado, Arkansas.

E. G. DAHLGREN was appointed acting secretary of the Interstate Oil Compact Commission, Oklahoma City, Oklahoma, effective July 1.

GEOLOGICAL AND GEOPHYSICAL SOCIETIES

COLORADO

ROCKY MOUNTAIN ASSOCIATION OF PETROLEUM GEOLOGISTS
DENVER, COLORADO

President - - - - - - - - - Ben H. Parker
Colorado School of Mines, and Frontier Refining Company

1st Vice-President - - - - - Dart Wantland
Colorado School of Mines

2nd Vice-President - - - - Wm. B. Kramer
U. S. Geological Survey

Secretary-Treasurer - - - - - J. J. Zorichak
Petroleum Administration for War
First National Bank Building

Luncheons every Friday noon, Cosmopolitan Hotel. Evening dinner (6:15) and program (7:30) first Monday each month or by announcement, Cosmopolitan Hotel.

ILLINOIS

ILLINOIS GEOLOGICAL SOCIETY

President - - - - - - - - - Fred H. Moore
Magnolia Petroleum Co., Box 535, Mt. Vernon

Vice-President - - - - - - - - Lee C. Lamar
Carter Oil Company, Box 568, Mattoon

Secretary-Treasurer - - - - Everett F. Stratton
Schlumberger Well Surveying Corporation, Box 491, Mattoon

Meetings will be announced.

INDIANA-KENTUCKY

INDIANA-KENTUCKY GEOLOGICAL SOCIETY
EVANSVILLE, INDIANA

President - - - - - - - - George R. Wesley
Skelly Oil Co.

Vice-President - - - - - - - Robert F. Eberle
The Superior Oil Company

Secretary-Treasurer - - - - Hillard W. Bodkin
The Superior Oil Company

Meetings will be announced.

KANSAS

KANSAS GEOLOGICAL SOCIETY
WICHITA, KANSAS

President - - - - - - - - - - Leo R. Fortier
Alpine Oil and Royalty Co.

Vice-President - - - - - - - Virgil B. Cole
Gulf Oil Corporation

Secretary-Treasurer - - - - Delbert J. Costa
Superior Oil Co. of California
417 First Natl. Bank Bldg.

Manager of Well Log Bureau - Harvel E. White

Regular Meetings: 7:30 P.M., Geological Room, University of Wichita, first Tuesday of each month. Visitors cordially welcomed.

The Society sponsors the Kansas Well Log Bureau which is located at 412 Union National Bank Bldg.

LOUISIANA

NEW ORLEANS GEOLOGICAL SOCIETY
NEW ORLEANS, LOUISIANA

President - - - - - - - - - H. C. Petersen
Freeport Sulphur Co., American Bank Bldg.

Vice-President and Program Chm. - - - - - - - - - - - - - - - - - Dean F. Metts
Humble Oil and Refining Company
1405 Canal Bldg.

Secretary-Treasurer - - - - - B. E. Bremer
The Texas Company, P.O. Box 252

Meets the first Monday of every month, October-May inclusive, 7:30 P.M., St. Charles Hotel. Special meetings by announcement. Visiting geologists cordially invited.

LOUISIANA

THE SHREVEPORT GEOLOGICAL SOCIETY
SHREVEPORT, LOUISIANA

President - - - - - - - - R. M. Wilson
Ohio Oil Company, Drawer 1129, Zone 91

Vice-President - - - - - - - - E. P. Ogier
c/o W. C. Spooner, Box 1195, Zone 90

Secretary-Treasurer - - - - - L. H. Meltzer
Union Producing Co., Box 1407, Zone 92

Meets the first Monday of every month, September to May, inclusive, 7:30 P.M., Criminal Court Room, Caddo Parish Court House. Special meetings and dinner meetings by announcement.

LOUISIANA

SOUTH LOUISIANA GEOLOGICAL SOCIETY
LAKE CHARLES, LOUISIANA

President - - - - - - - - - - C. B. Roach
Shell Oil Company, Inc., Box 136

Vice-President - - - - - - - P. S. Shoeneck
Atlantic Refining Company

Secretary - - - - - - - - - Ben F. Morgan
Stanolind Oil and Gas Company

Treasurer - - - - - - - - Robert N. Watson
Atlantic Refining Company, Box 895

Meetings: Dinner and business meetings third Tuesday of each month at 7:00 P.M. at the Majestic Hotel. Special meetings by announcement. Visiting geologists are welcome.

MICHIGAN

MICHIGAN GEOLOGICAL SOCIETY

President - - - - - - - Edward J. Baltrusaitis
Gulf Refining Company, Box 811, Saginaw

Vice-President - - - - - Raymond S. Hunt
Consulting, 405 S. Main, Mt. Pleasant

Secretary-Treasurer - - - - Thomas S. Knapp
The Chartiers Oil Co., Box 227, Mt. Pleasant

Business Manager - - - - - - - Lee S. Miller
Michigan Geological Survey,
Capitol Savings and Loan Bldg., Lansing

Meetings: Bi-monthly from November to April at Lansing. Afternoon session at 3:00, informal dinner at 6:30 followed by discussions. (Dual meetings for the duration.) Visiting geologists are welcome.

MISSISSIPPI

MISSISSIPPI GEOLOGICAL SOCIETY
JACKSON, MISSISSIPPI

President - - - - - - - - - K. K. Spooner
The Atlantic Refining Company, Box 2407

Vice-President - - - - - Lyman C. Dennis
Pure Oil Company, Box 1141

Secretary-Treasurer - - - - - C. L. Morgan
Consulting, Edwards Hotel

Meetings: First and third Wednesdays of each month, from October to May, inclusive, at 7:30 P.M., Edwards Hotel, Jackson, Mississippi. Visiting geologists welcome to all meetings.

OKLAHOMA

ARDMORE GEOLOGICAL SOCIETY
ARDMORE, OKLAHOMA

President - - - - - - - - - John Marshall
The Texas Company, Box 539

Vice-President - - - - - - - Frank Neighbor
Sinclair Prairie Oil Company

Secretary-Treasurer - - - - - - S. L. Rose
618 Simpson Building

Dinner meetings will be held at 7:00 P.M. on the first Wednesday of every month from October to May, inclusive, at the Ardmore Hotel.

OKLAHOMA

OKLAHOMA CITY GEOLOGICAL SOCIETY
OKLAHOMA CITY, OKLAHOMA

President - - - - - - - - - E. G. Dahlgren
Interstate Oil Compact Commission
State Capitol

Vice-President - - - - - Theodore G. Glass
Sinclair Prairie Oil Company
703 Colcord Building

Secretary-Treasurer - - - - - C. E. Hamilton
Consolidated Gas Utilities Corporation
814 Braniff Building

Meetings: Technical program each month, subject to call by Program Committee, Oklahoma City University, 24th Street and Blackwelder. Luncheons: Every Thursday, at 12:00 noon. Y.W.C.A. Cafeteria.

SHAWNEE GEOLOGICAL SOCIETY
SHAWNEE, OKLAHOMA

President - - - - - - - Roy D. McAninch
Stanolind Oil and Gas Company, Box 1099

Vice-President - - - - - - - E. R. Owen
Phillips Petroleum Company, Box 152

Secretary-Treasurer - - - - Marcelle Mousley
Atlantic Refining Company, Box 169

Meets the fourth Thursday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

TULSA GEOLOGICAL SOCIETY
TULSA, OKLAHOMA

President - - - - - - - - - J. V. Howell
912 Philtower

1st Vice-President - - - - - - W. H. Butt
Atlantic Refining Company

2nd Vice-President - - - - W. Reese Dillard
Consulting

Secretary-Treasurer - - - - - - - L. C. Case
Gulf Oil Corporation, Box 661

Editor - - - - - - - - - - Roy L. Ginter
U. S. Geological Survey

Meetings: First and third Mondays, each month, from October to May, inclusive, at 8:00 P.M., University of Tulsa, Kendall Hall Auditorium. Luncheons: Every Tuesday (October-May), Bradford Hotel.

TEXAS

CORPUS CHRISTI GEOLOGICAL SOCIETY
CORPUS CHRISTI, TEXAS

President - - - - - - - - - Ira H. Stein
Continental Oil Company, 604 Driscoll Building

Vice-President - - - - - Henry D. McCallum
Humble Oil and Refining Company

Secretary-Treasurer - - - - Elsie B. Chalupnik
Barnsdall Oil Company, 904 Driscoll Building

Regular luncheons, every Wednesday, Petroleum Room, Plaza Hotel, 12:05 P.M. Special night meetings, by announcement.

DALLAS PETROLEUM GEOLOGISTS
DALLAS, TEXAS

President - - - - - - - - Joseph M. Wilson
Continental Building

Vice-President - - - - - - Henry C. Cortes
Magnolia Petroleum Company

Secretary-Treasurer - - - - H. C. Vanderpool
Seaboard Oil Company

Executive Committee - - - - Cecil H. Green
Geophysical Service, Inc.

Meetings: Regular luncheons, first Monday of each month, 12:00 noon, Petroleum Club, Adolphus Hotel. Special night meetings by announcement.

TEXAS

EAST TEXAS GEOLOGICAL SOCIETY
TYLER, TEXAS

President - - - - - - - - - G. J. Loetterle
Shell Oil Company, Inc., Box 2037

Vice-President - - - - - - - - B. W. Allen
Gulf Oil Corporation

Secretary-Treasurer - - - - - - L. L. Harden
Sinclair Prairie Oil Company, Box 1110

Executive Committee - - - - J. H. McGuirt
Magnolia Petroleum Company

Meetings: Monthly and by call.
Luncheons: Every Monday at 12:00 noon, Blackstone Hotel

FORT WORTH GEOLOGICAL SOCIETY
FORT WORTH, TEXAS

President - - - - - Joseph H. Markley, Jr.
The Texas Company, Box 1720

Vice-President - - - - - - James L. Morris
The Pure Oil Company, Box 2107

Secretary-Treasurer - - - Spencer R. Normand
Independent Exploration Company
2210 Ft. Worth Natl. Bank Bldg.

Meetings: Luncheon at noon, Hotel Texas, first and third Mondays of each month. Visiting geologists and friends are invited and welcome at all meetings.

HOUSTON GEOLOGICAL SOCIETY
HOUSTON, TEXAS

President - - - - - - - - - Leslie Bowling
Union Oil Company of California

Vice-President - - - - - - W. B. Milton, Jr.
Gulf Oil Corporation

Secretary - - - - - - - - - - - W. B. Moore
Atlantic Refining Company, Box 1346

Treasurer - - - - - - - - - - G. J. Smith
Pan American Producing Company

Regular meeting held the first and third Thursdays at noon (12 o'clock), Mezzanine floor, Texas State Hotel. For any particulars pertaining to the meetings write or call the secretary.

NORTH TEXAS GEOLOGICAL SOCIETY
WICHITA FALLS, TEXAS

President - - - - - - - - Donald Kelly
The Texas Company

Vice-President - - - William Lloyd Haseltine
Magnolia Petroleum Co., Box 239

Secretary-Treasurer - - - David T. Richards
Shell Oil Co., Inc., Box 2010

Luncheons and evening programs will be announced.

SOUTH TEXAS GEOLOGICAL SOCIETY
SAN ANTONIO, TEXAS

President - - - - - - - Robert N. Kolm
Atlantic Refining Co., 1742 Milam Building

Vice-President - - - - - Donald O. Chapell
Transwestern Oil Co., 1600 Milam Building

Secretary-Treasurer - - - Robert D. Mebane
Saltmount Oil Co., 916 Milam Building

Meetings: One regular meeting each month in San Antonio. Luncheon every Monday noon at Milam Cafeteria, San Antonio.

WEST TEXAS GEOLOGICAL SOCIETY
MIDLAND, TEXAS

President - - - - - - - - Robert I. Dickey
Forest Development Corporation

Vice-President - - - - - - George R. Gibson
Richfield Oil Corporation

Secretary-Treasurer - - - - - - - Jane Ferrell
Magnolia Petroleum Company, Box 633

Meetings will be announced

WEST VIRGINIA

THE APPALACHIAN GEOLOGICAL SOCIETY
CHARLESTON, WEST VIRGINIA
P. O. Box 2385

President - - - - - - - Douglas Rogers, Jr.
South Penn Natural Gas Company, Parkersburg

Vice-President - - - - - - Veleair C. Smith
Kanawha Valley Bank Building

Secretary-Treasurer - - - - - Charles E. Stout
United Fuel Gas Company, Box 1273

Editor - - - - - - - - - H. J. Simmons, Jr.
Godfrey L. Cabot, Inc., Box 1473

Meetings: Second Monday, each month, except June, July, and August, at 6:30 P.M., Kanawha Hotel.

THE SOCIETY OF EXPLORATION GEOPHYSICISTS

President - - - - - - William M. Rust, Jr.
Humble Oil & Refining Company, Houston, Texas

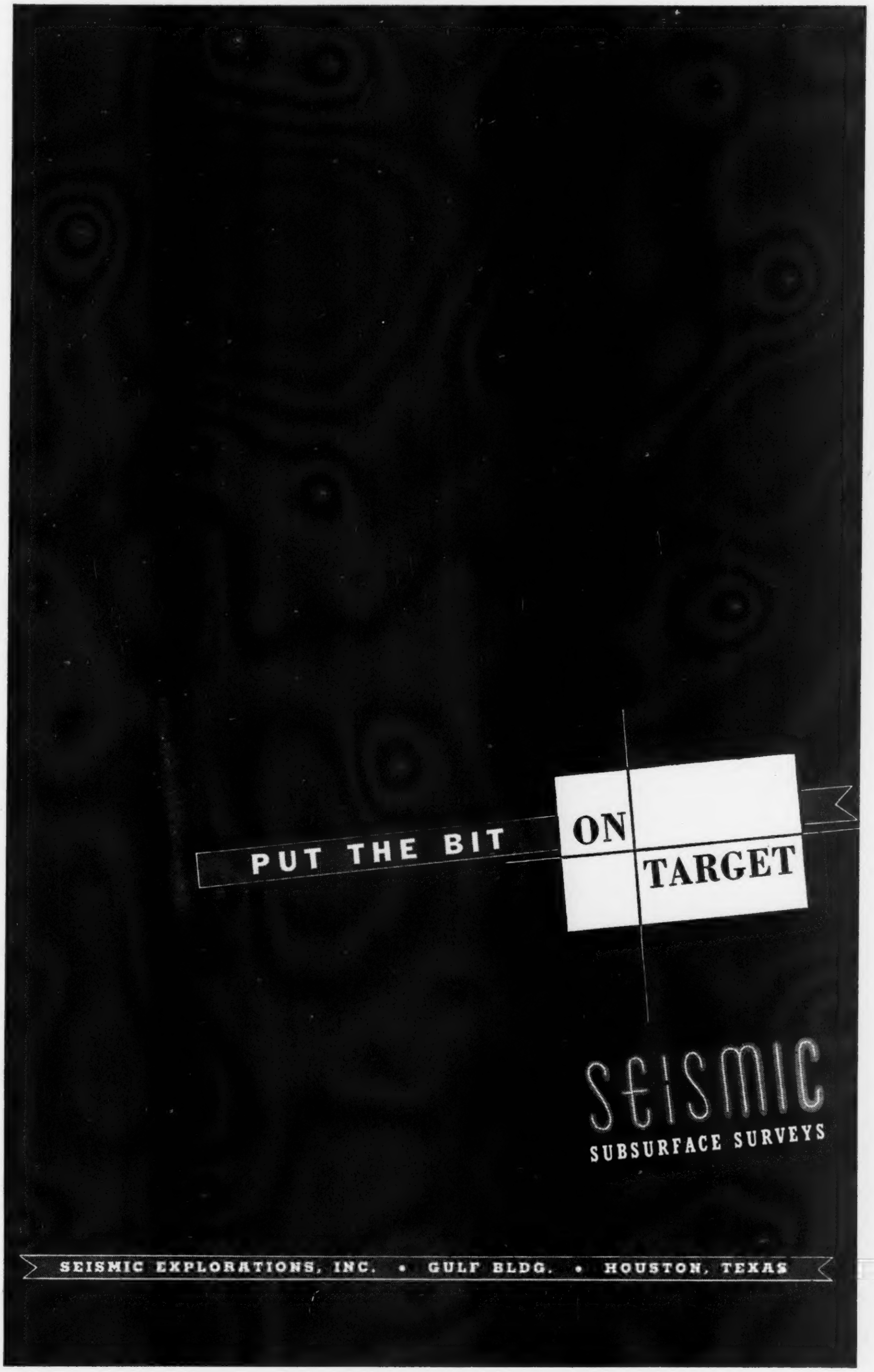
Vice-President - - - - - - Henry C. Cortes
Magnolia Petroleum Company, Dallas, Texas

Editor - - - - - - - - - Joseph A. Sharpe
Stanolind Oil and Gas Company, Tulsa, Oklahoma

Secretary-Treasurer - - - - W. Harlan Taylor
Petty Geophysical Engineering Company
1449 Esperson Bldg., Houston, Texas

Past-President - - - - - - - - R. D. Wyckoff
Gulf Research and Development Company
Pittsburgh, Pennsylvania

Business Manager - - - - - - - J. F. Gallie
P.O. Box 410, El Dorado, Arkansas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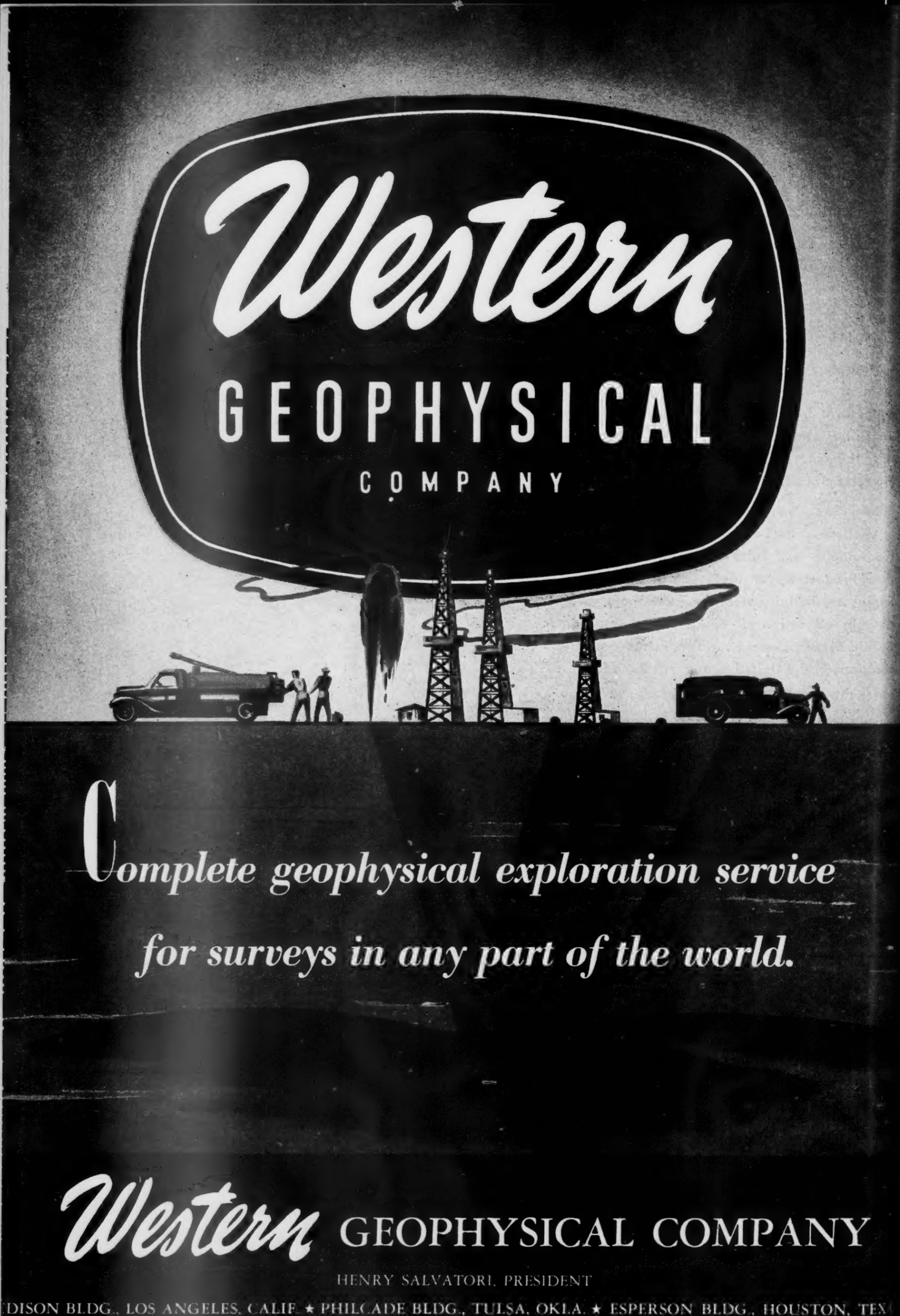

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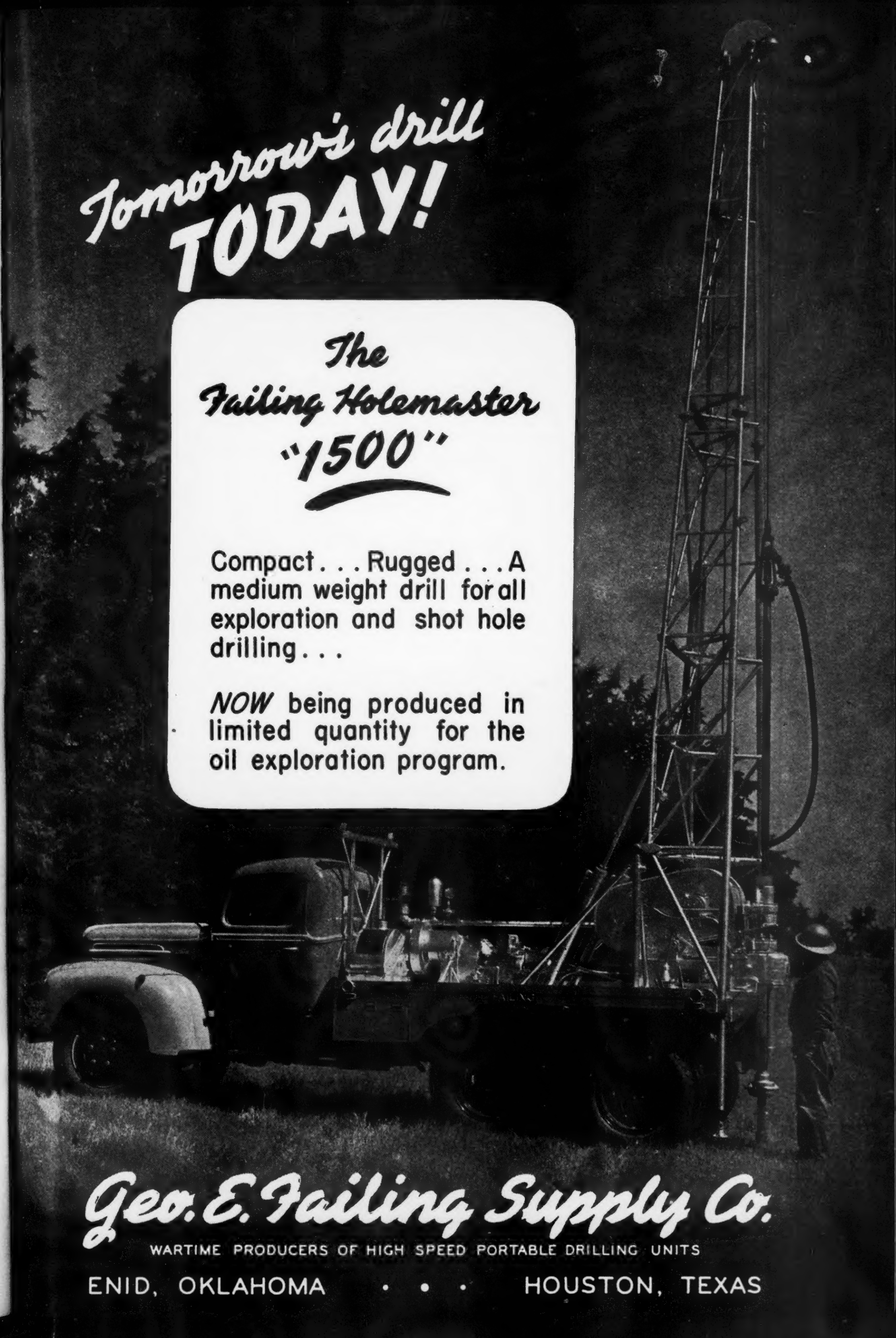

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